10 cc. g. f.   5, 5 $\frac{n}{10}$ Na OH. (Phenol.ph)

10 "   "   4. 0   "   "   dimethyl.

15 "   "   0, 5   "   "   alizarin

Aliz = every thing minus Comb. HCl.

$$
\begin{array}{r}
.020 \quad \text{total} \\
-.014 \\
\hline
.006 = \text{Every except}
\end{array}
$$

Free HCl.

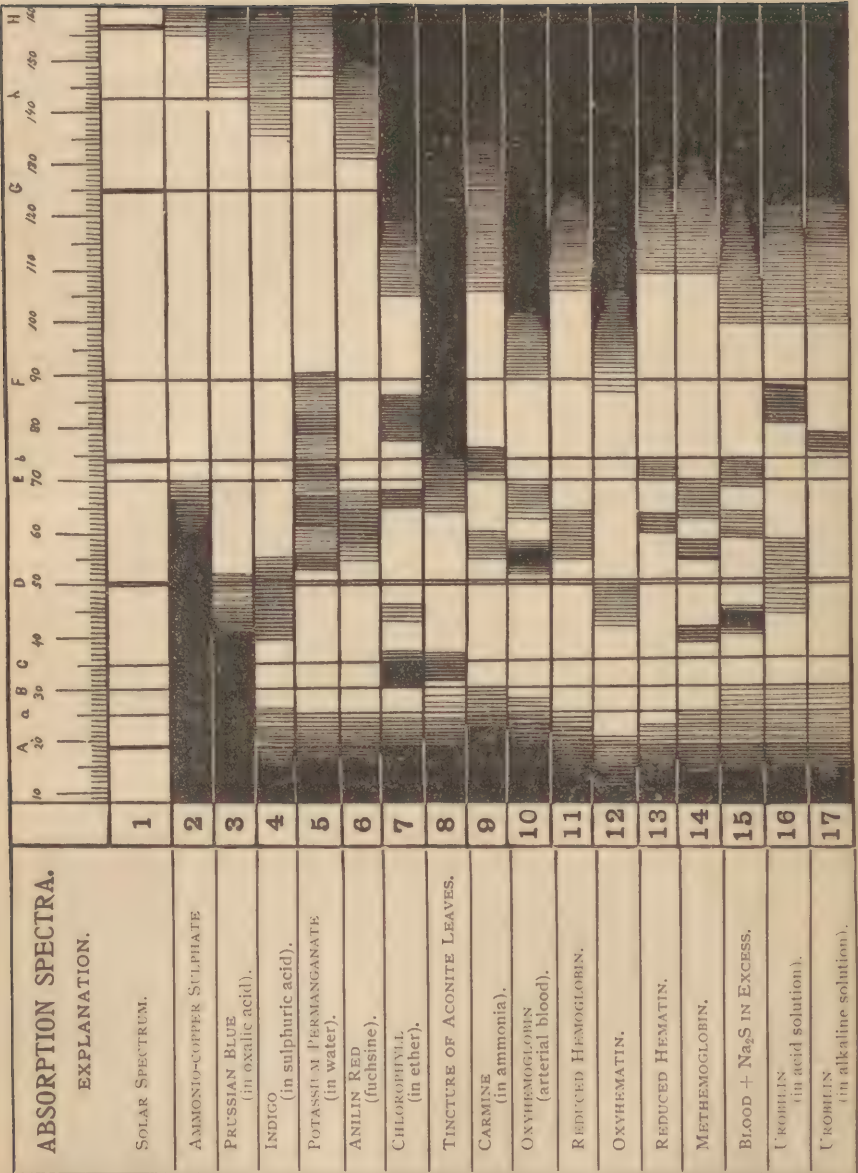$3\frac{637}{1000}$ milligrams

1820

MEDICAL AND PHARMACEUTICAL
CHEMISTRY

BARTLEY

ABSORPTION SPECTRA. EXPLANATION.																		
		A	a	B	C		D		E b		F		G		h	H		
		20		30	40		50	60	70		80	90	100	110	120	130	140	150	160
SOLAR SPECTRUM.	1																		
AMMONIO-COPPER SULPHATE	2																		
PRUSSIAN BLUE (in oxalic acid).	3																		
INDIGO (in sulphuric acid).	4																		
POTASSIUM PERMANGANATE (in water).	5																		
ANILIN RED (fuchsine).	6																		
CHLOROPHYLL (in ether).	7																		
TINCTURE OF ACONITE LEAVES.	8																		
CARMINE (in ammonia).	9																		
OXYHEMOGLOBIN (arterial blood).	10																		
REDUCED HEMOGLOBIN.	11																		
OXYHEMATIN.	12																		
REDUCED HEMATIN.	13																		
METHEMOGLOBIN.	14																		
BLOOD + Na₂S IN EXCESS.	15																		
UROBILIN (in acid solution).	16																		
UROBILIN (in alkaline solution).	17																		

TEXT-BOOK

OF

MEDICAL AND PHARMACEUTICAL

CHEMISTRY

BY

ELIAS H. BARTLEY, B.S., M.D., Ph.G.

PROFESSOR OF CHEMISTRY AND TOXICOLOGY IN LONG ISLAND COLLEGE HOSPITAL; DEAN AND
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ASSO'N; OF THE AMER. CHEM. SOC.; FELLOW OF THE AMER.
ASSOC'N FOR THE ADVANCEMENT OF SCIENCE, ETC.

FIFTH EDITION, REVISED AND ENLARGED

With Ninety=six Illustrations

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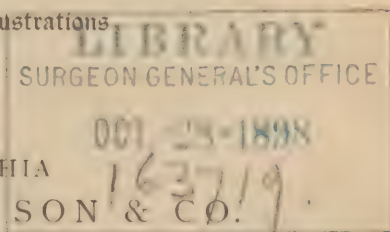
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PREFACE

TO THE FIFTH EDITION.

The call for a new edition of this book has afforded the author an opportunity to again thoroughly revise the text, and correct the errors and defects of the last edition.

The experience of the three years since the appearance of the fourth edition has brought to light many typographical errors and some minor defects, which have been corrected with as much care as possible. The author has endeavored to bring the book up to date, and has found it necessary to rewrite some portions, especially in parts IV and V.

The chapters on Nutrition, the Clinical Examination of Milk, Gastric Contents, Vomit, and Feces have been largely rewritten. The general plan of the book in other respects has not been changed. It has been thought not advisable to increase the size of the book, and no new synthetic remedies have been added to those to be found in the last edition.

The nomenclature used in the fourth edition has been retained, for the reasons stated in the preface, which I here quote:

"Since the professions of medicine and pharmacy are largely governed by the Pharmacopœia, and as the Committee of Revision of this work 'deemed it unsafe and unnecessary to inaugurate such radical changes, not yet generally accepted or followed in practice,' and have retained the established spelling and names of chemical terms, it seemed best to the author to conform to the usage of this official standard. For this and other reasons the established spelling has been retained, so far as it concerns those substances which are official. In the case of those organic substances which are unofficial,

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and not so often met with in pharmacy, and the new remedies, the proposed new spelling has been adopted. It is by no means certain that the reform spelling of chemical terms, as suggested by the American Association for the Advancement of Science, will be accepted by chemists in other English-speaking countries; and as physicians and pharmacists will use the spelling of the Pharmacopœia for at least ten years to come, the author felt justified in this somewhat inconsistent plan of a gradual change to the new spelling, instead of an abrupt one.

" That students may become acquainted with the proposed changes, the rules for the new spelling will be found published in the Appendix. Teachers are advised to call special attention to this subject."

The author renews his obligation to various authors whose works he has freely consulted, although the list would be too long to mention here. He is especially indebted to Allen's " Commercial Organic Analysis," Haliburton's " Text-book of Chemical Physiology," Hammersten's " Physiologische Chemie," Gautier's " Cours de Chimie," Lea's " Chemical Basis of the Human Body." Helbing's " Modern Materia Medica." He is indebted to Leffmann and Beam's " Milk Analysis " and " Water Analysis " for several cuts of apparatus, and to Landois and Stirling's " Human Physiology," from which a number of cuts have been borrowed.

The official names of medicinal chemicals, according to both the United States and the British Pharmacopœias, in most cases have been given. The author would gratefully acknowledge the receipt of valuable suggestions from teachers, and is especially indebted to Mr. Joseph Kahn, Phar. D., for assistance in the revision of the text.

E. H. B.

BROOKLYN,
  September, 1898.

PREFACE

TO THE FIRST EDITION.

This book is designed especially as a text-book for medical students during their attendance upon lectures. It is believed, however, that it will be found of use to the physicians, as a book of ready reference. It is the result of the author's experience as a teacher of Chemistry during the past twelve years, and its plan and much of the subject-matter are essentially that given by him in his lectures at the Long Island College Hospital for the last six years.

While there are numerous good text-books on Chemistry in the market, the medical student often complains that they are either too voluminous for his limited time, and contain a great deal of matter not directly bearing upon the science of medicine, or, on the other hand, are too brief to be of any service to him. It has been the aim, in preparing this book, to avoid these extremes and fill the gap now existing between them.

The plan of the work required a careful selection from the mass of material at hand. The book is largely a compilation, and the author claims little originality in the subject-matter it contains, but has used his own judgment in its selection and arrangement.

From the large number of subjects treated, it has been necessary to be very brief in the descriptions of individual substances, but all general principles and the relations of the facts of the science to medicine have been more fully stated. Much pains has been taken to condense the matter as much as is consistent with clearness.

In part I are presented such fundamental facts in Chemical Physics as seemed necessary for the proper understanding of the descriptive parts, and to explain the theory and use of thermometers, the spectroscope, medical batteries, etc.

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It has been found best, in the author's past experience, to present the elementary theories of Chemistry before entering upon the natural history of the elements and their compounds ; and this has been done as clearly and concisely as possible in part II, giving only what was considered necessary to the proper understanding of all the facts to be presented in the later parts. The subjects of Notation, Nomenclature, and Chemical Reactions have been dwelt upon as of first importance to the student.

In part III the natural history of the Elements and principal compounds are briefly presented, with their physiological and toxicological bearings.

In part IV only those organic compounds are treated with which the physician will be likely to meet. The space that could be given to this part necessitated very short descriptions. The Appendix contains some tables and analyses which will greatly enhance its value as a reference book.

The Chemistry of the tissues and secretions have been omitted, as belonging to the domain of physiological chemistry. It would be impossible to mention all the works upon which the author has drawn for his facts.

Besides the credit given in the text, he wishes to acknowledge his indebtedness especially to Cooke's "Chemical Philosophy"; Barker's, Richter's, Witthaus', Fowne's, and Rand's text-books ; De Watteville's and Jenkins' books on electricity ; Prescott's " Proximate Organic Analysis"; Wurtz's " Dict. de Chimie " and " Chemie Biologique"; Charles' " Physiolog. Chem."; Schorlemmer's, Strecker's, and Pinner's "Organic Chemistry," and the " U. S. Pharmacopœia." I would here express my thanks to my friend and assistant, Dr. W. M. Hutchinson, for valuable assistance in preparing the work; also to Mr. W. H. Kent, Ph.D., for similar assistance.

As this work is prepared especially for the medical student. it is to him that I shall trust for its reception, hoping that the labor I have bestowed upon it may help to lessen his.

BROOKLYN, N. Y.,
    Sept. 1st, 1885.

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PART I.

PART II.

PART IV.

PART V.

MEDICAL CHEMISTRY.

PART I.

INTRODUCTION.

DEFINITIONS.—Science is a systematic and orderly arrangement of knowledge. It is founded upon observation and experiment. A **theory** is a deduction from established facts, and occupies a prominent place in science. A **hypothesis** is a supposition brought forward to explain facts or phenomena. **Natural science** treats of the external appearance and internal structure of natural objects. Examples: Botany, zoölogy, and mineralogy deal with the classification and structure of plants, animals, and minerals respectively, and are, therefore, natural sciences.

Physical science treats of the properties and phenomena of the matter of which bodies are composed. **Matter** is anything whose existence is revealed to us by our senses. The **properties** of a body are the peculiar qualities by which it makes itself known to us; as color, solidity, odor, taste, etc. **Physics** is that branch of physical science which treats of the phenomena presented to us by **bodies** or **masses** of matter as such.

Chemistry is that branch of physical science which treats of the ultimate composition of bodies, and the changes which this composition may undergo.

Physics teaches us that water is hot or cold; that it may exist as steam, liquid water, or solid ice. Chemistry tells us that it is composed of two gases, called hydrogen and oxygen, in the proportion of 2 of the former to 1 of the latter, by volume, and 1 of the former to 8 of the latter, by weight. It also teaches us how we can prove this to be true.

Matter exhibits certain properties which are common to all bodies, and which are therefore called the **general properties** of matter; such as indestructibility, impenetrability, divisibility, mobility, gravi-

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tation, molecular attraction, chemism, and inertia.   **Specific properties** are such as are observed in certain bodies only ; such as color, hardness, fluidity, transparency, etc.

Matter is Indestructible.—What we generally term destruction is merely a change of form. When wood burns it is only changed into invisible gases, which go off into the air. These gases may be collected, and by analysis we may get back the elements of the wood again. Whatever changes we may produce in a body or mass of matter, we can neither create nor destroy one particle of it ; the same weight of matter remains after the change, as before.

Matter is Impenetrable.—That is, two portions of matter can not occupy the same place at the same time. Strictly speaking, this applies only to the ultimate particles of a body. In many phenomena bodies do seem to penetrate each other. For instance, the volume of a mixture of salt and water, or of alcohol and water, is less than the sum of the volumes before they are mixed. In these cases the penetration is only apparent. The penetration of the water by the salt is due to the fact that water, like all other bodies, is porous ; that is, it has spaces or interstices between the ultimate particles of which the mass is composed, which are unoccupied by matter, and into which the particles of salt crowd themselves.

Divisibility.—Three divisions of matter are recognized—viz., **masses, molecules, and atoms.**

A **mass** or **body** is any distinct portion of matter appreciable to the senses.

A **molecule** (a little mass) is the smallest particle of matter that can be obtained by subdividing a mass by mechanical or physical means. A molecule of chalk is the smallest particle of chalk that can exist. The molecules are too small to be seen by the aid of the most powerful microscope ; their size, however, is approximately known.*

An **atom** is the smallest particle into which any given kind of matter can be divided. The atom is, as yet, a hypothetical body. It is one of the component parts of a molecule, and the smallest particle that can enter into the formation of a molecule.

The atom is, therefore, supposed to be an indivisible solid body, with a definite and unchangeable weight, possessing a definite quantity of force of attraction for other atoms, which force is neutralized by the approach of the requisite number of atoms.

Atoms, when left to themselves, will not, as a rule, remain uncombined, but collect in groups, because of their attraction for one another.

A molecule is a collection of atoms, and a collection of molecules forms a mass.

Mobility.—All matter is in a state of constant motion. The motion of masses, or **mechanical motion,** is treated of in works on mechanics. The motions of molecules give rise to the phenomena grouped under the name of the so-called **physical forces. Light, heat, electricity,** and **magnetism** are different manifestations of the motions of the molecules composing the body which exhibits them. Of the motions of atoms little is known with certainty.

Gravitation is an attraction which exists between all masses of matter. The law of gravitation states that **the force of gravitation is directly proportional to the mass, and inversely proportional to the square of the distance.** That is, the attraction between any two bodies will be four times as great when one foot apart as when two feet apart.

What is known as the weight of a body, is the measure of the attraction between it and the earth, at or near the surface of the latter. For table of weights, see Appendix.

By **mass,** here, we mean the **weight** of matter, and not the **volume.**

By **specific gravity** (sp. gr.) is meant the relative weight of equal volumes of bodies, assumed to be under like conditions of temperature and pressure. For the purpose of comparing the weights of equal volumes of different bodies, they are all referred to an assumed standard. The standard for liquids and solids is pure water weighed at a temperature of 4° C. (39° F.), the temperature at which it possesses the greatest density, or specific gravity.

Density is sometimes used as synonymous with specific gravity. Sulphur, whose specific gravity is 2, weighs twice as much, volume for volume, as pure water; while alcohol, whose specific gravity is 0.825, weighs 0.825 times as much as pure water, volume for volume.

In taking the specific gravity of gases or vapors, the standard of comparison is pure, dry air. In chemistry, however, it is more convenient to refer specific gravities of gases to hydrogen gas, and designate this as the density and not the specific gravity, which term refers to air as the standard. The density of hydrogen gas is therefore 1.

The density of pure air is 14.44—*i. e.*, air weighs, volume for volume, 14.44 times as much as hydrogen, both gases being weighed at the same temperature and under the same pressure. Density is a very important factor in the study of chemistry, and should be well understood. The sp. gr. of solids may be determined by first weighing the body in the air, and then in water at the required temperature. This is done by suspending the body from one beam of a balance by a thread or fine wire. To weigh in water it is only necessary to place a

vessel of water so that the suspended body may hang in the water or float upon it. **A body which sinks in water displaces a volume of water equal to its own, and loses a weight just equal to the weight of the water displaced.** The loss in the weight of the body when weighed in water will, therefore, be the weight of its own volume of water. By dividing the weight of the body in air by the loss of weight in water, the sp. gr. is obtained.

Thus, suppose a body weighs 6.200 gm. in air and 3.100 gm. in water. The loss of weight in water is 6.200 — 3.100 = 3.100 gm., which represents the weight of the water displaced by the body, or the weight of its volume of water. The sp. gr. of the body will then be found by dividing its weight in air, or 6.200 gm., by the weight of an equal volume of water, or 3.100 gm., giving a sp. gr. of 2.

When the body in question will not sink we may attach a sinker to it whose weight in air and loss of weight when suspended in water are known. The weight of the body in air is taken, the sinker attached, and both lowered into the water and again weighed. The loss in weight will represent the loss of weight of both the solid and sinker. Deduct the loss of the sinker, and the remainder will represent the weight of a volume of water equal to that of the body in question, whence the sp. gr. may be found as above. Bodies which are soluble in water may be suspended in some liquid of known sp. gr. in which they are insoluble.

Thus, let it be desired to obtain the sp. gr. of a lump of cane sugar. Suppose it weighs in air 100 gm., and in oil of turpentine (sp. gr. 0.87) 45.62 gm. Loss = 100 — 45.62 = 54.38 gm. 100 ÷ 54.38 = 1.84 as the sp. gr. referred to turpentine. Multiply this result by 0.87, the sp. gr. of the turpentine, and we have 1.60 as the true sp. gr. of the sugar.

The sp. gr. of a powder is obtained by partly filling a small flask or bottle with it and weighing both, the weight of the empty flask, as well as the weight of water it will contain, having been previously ascertained. The flask is then filled with pure water and again weighed. The difference between the last weight and the first will be the weight of the water in the flask. The difference between this weight and the weight of the water the flask will contain when full, will give the weight of the water displaced by the powder, from which the sp. gr. may be obtained as above.

The sp. gr. of liquids is obtained by means of the flask above mentioned, called a **picnometer** or **specific gravity flask**, made to contain a certain number of grams or grains of water at a temperature

of 60° F., its capacity being marked upon it. (See Fig. 1.) To take the sp. gr. of a liquid it is only necessary to weigh the flask, filled with the liquid in question brought to the requisite temperature, deduct the weight of the flask, and divide this result by the marked contents of the flask. The sp. gr. of liquids is frequently determined also by an instrument called a hydrometer.

Hydrometers are long, narrow, glass or metal tubes, having a chamber near the bottom filled with air, to make it float upright, and a smaller one below this containing enough mercury or small shot to sink it to a convenient depth in water. The hydrometer (see Fig. 2) acts upon

FIG. 1.

the principle of Archimedes, that a body specifically lighter than a liquid sinks in it until it displaces a volume of liquid whose weight is equal to its own, when it becomes stationary. The long, narrow stem composing the upper end of the instrument bears a scale indicating the sp. gr. by the depth to which the scale sinks in the liquid.

Hydrometers are of two kinds: (1) for fluids heavier than water, and (2) for fluids lighter than water. Special hydrometers are constructed for use in certain special liquids, and some with a scale giving arbitrary degrees and not sp. gr.

The Twaddell hydrometer, for example, used for liquids heavier than water, is so graduated that the degrees on the scale multiplied by 5 and added to 1000 give the sp. gr. compared with water. The **lactometer** is a hydrometer with a scale specially constructed for the examination of milk. The **urinometer** is a hydrometer whose scale is made to include the variations in sp. gr. found in urine.

FIG. 2.

To determine the sp. gr. of liquids with the hydrometer, it is only necessary to drop the instrument into the liquid, which must be at the temperature for which the instrument is constructed,—which, in this country, is usually 60° F.,—and then read off the sp. gr. on the scale at the surface of the liquid. (See Appendix for table of sp. gr. of chief liquids of U. S. P.)

Molecular Attraction—Molecules attract one another, as well as masses. When molecules of the same kind attract one another they form a homogeneous mass, and the force acting between them is called **cohesion**; when the molecules are unlike it is called **adhesion**. A body on being thrust into water comes out wet, because the water adheres to the body; but if you attempt to pull it apart, cohesion keeps it together.
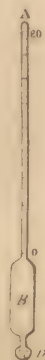
Chemism.—Atoms attract one another by a force called **chemism** or **chemical affinity.** Chemism holds atoms together to form molecules. It is to the molecule what cohesion is to the mass. Like cohesion, it only acts across inappreciable spaces.

Inertia is that property of matter by virtue of which it has no power in itself to change its condition. This term is often incorrectly limited to the tendency of a body when in motion to continue in motion, and when at rest to remain so. Chemical or physical changes never take place without the intervention of some external agency.

Extension is that property of matter by virtue of which it occupies space. Its relative degree is obtained by means of weights and measures. The system of measures and weights in use in all scientific works is that known as the **metric** or **decimal system.** In most American and English medical books, though not in all, the English system is employed, while all nations of Continental Europe use the metric system; so that it is requisite that the student should be familiar with both. The unit of the metric system is the meter. The **meter** * is the length of a platinum bar deposited in the public archives of France, and is 39.37 inches in length. The measure was obtained by taking $\frac{1}{10000000}$ part of the quadrant of a meridian of the earth, or of the distance from the equator to the pole. The ratio of increase and decrease of the system is decimal, and consequently this system is sometimes known as the **decimal system.** The multiples of all the measures and weights are denoted by Greek numerals, used as prefixes, as will be seen by reference to the **tables of weights and measures in the Appendix.** Thus, in measures of length we have the meter, **deka**meter, **hecto**meter, and **kilo**meter. The subdivisions are denoted by the Latin numerals, thus: meter, **deci**meter, **centi**meter, and **milli**meter.

GREEK.	LATIN.	ENGLISH.
Deka.	Decem.	Ten.
Hekaton.	Centum.	One hundred.
Chilios.	Mille.	One thousand.
Murias.		Ten thousand.

The decimal subdivisions and multiples give a simplicity to the tables which enables them to be easily learned and remembered, and brings into use in all calculations the easiest arithmetical processes. In square measure, measures of capacity, and measures of volume but

---

* Also spelled " metre."

few denominations are in common use, and these only are given in the table.

The **liter,** or cubic decimeter, is equal to 1000 cubic centimeters. The cubic centimeter (abbreviated c.c.) and tenths of c.c. are the only denominations in common use for quantities less than the liter. The half-liter and quarter-liter are also used. Measures of weight are derived from measures of volume, as follows:

The **gram,** the unit of weight, is the weight of one c.c. of distilled water, weighed in a vacuum, and at the temperature of 4° C. (39.2° F.), the temperature at which water has the greatest density.

Theoretically, the unit of weight is derived from that of capacity, as above; but the gram is really determined by reference to an original standard kilogram weight adopted by the French Government.

The capacity of vessels is determined, not by measure, but by weighing the water they will hold at a selected temperature.

A liter measure is, therefore, a vessel that will hold exactly a kilogram (1000 gm.) of pure water at the temperature at which it is to be used. Measuring instruments are usually made of glass, and are made to hold their marked contents at a temperature of 60° F. (15.5° C.) or 62° F. (16.6° C.).

The following table will be found convenient to memorize, in order to facilitate mental calculations where approximate values only are desired:

1 Meter	= 39.37 inches	= 3¼ feet.
1 Decimeter	= 10 centimeters	= 4 in.
1 Liter	= 1 quart	= 2 pints.
1 Gram	= 15½ grains.	
1 Kilogram	= 2.2 pounds avoirdupois.	
1 Grain	= 0.065 gram.	
℥j or f ℥j	= 4 grams, or 4 c.c.	
℥j or f ℥j	= 30 grams, or 30 c.c.	

The Metric System in Prescriptions.—In prescription writing it will be found convenient to adopt the following rule where the doses have been learned in grains: Make f ℥j equal thirty c.c.—*In a two-ounce mixture (sixty c.c.), when a teaspoonful is to be given as a dose, write as many grams as there are grains or minims required in each dose.* Thus, suppose it be desired to write for a two-ounce mixture containing fifteen grains of potassium bromide in each fluidrachm; it would be written:

> Grams.
> ℞. Potass. bromidi, . . . 15|000
> Aquæ, ... 60|000, or 60 c.c.
> M. Sig.—4 c.c. ter die.

A f ℥ iij mixture would be written with one and one-half times as many grams as there are grains required in each dose :

                                    Grams.
          ℞.   Potass. bromidi, . . . 22|500
                Aquæ, ... 90|000, or 90 c.c.
          M.   Sig.—4 c.c. ter die.

The perpendicular line is used here to occupy the position of the decimal point, and to separate grams from milligrams.

It is customary with some pharmacists to weigh all quantities written as above, instead of measuring them. In such cases it is well to remember that **liquors** have very nearly the same sp. gr. as water, excepting those containing the salts of the heavy metals. The **syrups** and **glycerita** have a sp. gr. of about 1½. The **tinctures** have a sp. gr. of about 0.9. In cases of doubt about the sp. gr., direct the quantity in cubic centimeters, when it will be measured.

CHEMICAL PHYSICS.

Three States of Matter.—The same body may exist in three states ; as a solid, liquid, or gas. Most solid bodies can be changed into the liquid or gaseous state by the application of heat. For example, when ice is heated it melts and assumes the liquid form ; if we apply heat to the water, it expands, is converted into steam, and tends to escape from the vessel containing it. If we confine the steam, it exerts a strong pressure upon the walls of the vessel, which increases with the temperature. This and other similar facts have led to the adoption of the word **force** to express the nature of heat. The term **heat force** may often be found in works on physics. The capacity which this force possesses of performing work is known as **energy.** Cohesion has been defined as that force or attraction which acts between similar molecules to hold them together to form a body or mass. From the above illustration we see that heat, whatever it may be, acts in opposition to cohesion, and even destroys it altogether, driving the molecules off into space. We have in this, then, the explanation of the three states of matter. In the **solid state,** cohesion is greater than the opposite repellent force of heat, and the molecules are in very close apposition. In the **liquid state,** cohesion and the repellent force are nearly equal, the molecules being free to move in any direction, and to obey the law of gravity—*i. e.,* they all tend to seek the lowest level. In the **gaseous state,** the repellent force of heat has entirely overcome the attraction of the molecules for one another ; hence, they tend to fly off into space, and will do so

unless confined in a vessel. If we withdraw the heat from a gas, or if we compress it sufficiently, we may reduce it to a liquid, and in many cases to a solid—*i. e.*, we bring cohesion into play again.

It will be easy to understand, from the above, that the molecules must be farther apart in steam than in water, and in water than in ice. What is true of water is true of all bodies capable of existing in the three states; for heat expands all bodies, whether solid, liquid, or gaseous, although not to the same extent. Gases expand more than liquids or solids for the same rise in temperature. Gases are more simple in their constitution than either liquids or solids, and hence we get a better knowledge of their structure.

Critical Temperature.—As stated above, all gases can be condensed to liquids if we can secure a sufficiently low temperature and enough pressure. Pressure alone will not succeed, nor will temperature alone. It is found that every gas has a **critical temperature** —*i. e.*, a temperature above which no amount of pressure will condense it to a gas. This temperature is not the same for all gases. The following is a list of a number of the common gases, with their critical temperatures :

Nitrogen, ... —146.0° C.	Nitrous oxide, ... 35.4° C.
Carbon dioxide, ... 31.9° C.	Ammonia, ... 130.0° C.
Oxygen, ... —118.8° C.	Chlorine, ... 141.0° C.
Carbon monoxide, ... —140.0° C.	Sulphur dioxide, ... 155.4° C.
Acetylene, ... 37.0° C.	

Tension of Gases.—From the last article it will be understood that the molecules of a gas are continually bombarding the walls of a vessel containing it. The effect of these bombardments is to produce an expansive tendency upon the walls of the vessel, which is usually balanced by a similar bombardment of the molecules of the air on the outside.

This tendency of a confined gas to escape is called its tension or pressure.

When the tension or pressure of a gas is much above that of the surrounding atmosphere, it is usually measured by a pressure-gage. Usually, however, gases are handled at the pressure of the air. As we shall see later, it is important to have some ready and accurate method for measuring the pressure the atmosphere exerts upon other gases, and which determines their tensions. For this purpose the barometer is used. It is constructed as follows : A thick glass tube about thirty-six inches long, and sealed at one end, is bent upon itself near the other end so as to leave the long arm a little more than thirty inches in length. The long limb is now filled with pure mercury, inverted, and

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the mercury boiled throughout the entire length, to expel all air.   On re-inverting the tube a part of the mercury runs down into the shorter arm, until that in the longer stands about thirty inches (760 mm.)

FIG. 3.

above that in the shorter.   It is now only necessary to mount the tube and provide some means of measuring the difference in height between the surfaces of the mercury in the two arms.   In the instrument represented in figure 3, the tube is graduated at two points covering the variations likely to be met with in the barometer.   The scale on the long arm is made by measurement from a zero point on the short arm, and may be in inches or millimeters.   The short arm is graduated from the zero point both upward and downward.   When the surface of the mercury in the short arm is above the zero mark, the distance in inches or millimeters is to be deducted from the reading on the long arm ; if below the zero mark, the two readings are to be added.   Other methods of reaching the same result are in use.

The greater the pressure of the air upon the mercury in the short arm, the higher will it raise the mercury in the longer arm, and *vice versâ*.

By means of the barometer we may measure the pressure or tension of the air.   The volume of a given mass of gas under a constant pressure varies with the absolute temperature.   (See p. 27.)

Law of Mariotte.—This law is stated as follows : **The volume of a confined gas is inversely proportional to the pressure brought to bear upon it ;** that is, the less the pressure the greater the volume, and the greater the pressure the less the volume.   Stated algebraically this law is : $P : P' :: V' : V$, whence $V' = \frac{PV}{P'}$, in which expression P and P' stand for two different pressures, and V and V' for the corresponding volumes.   The pressure exerted upon any mass of gas is usually that of the surrounding atmosphere, and is measured by a barometer.   The normal pressure of the air is about fifteen pounds to the square inch, or such that it will support a column of mercury 760 mm. (thirty inches) in height.   In the expression of pressures, as measured by this instrument, the height of the column of mercury is employed instead of the weight of the column.   Thirty inches of mercury is used instead of fifteen pounds' pressure.   Substituting this form of statement in the above expression, it becomes $V : V' :: H' : H$ and $V' = \frac{VH}{H'}$, or $V H = V' H'$, in which H and H' stand for the height of the barometric column.

Example.—A certain volume of air, at a pressure of 742 mm., measures 540 c.c.; what will it measure at 760 mm.? By the above formula we will have $V' = \frac{540 \times 742}{760} = 527.2$ c.c.; or, 540 c.c. : x : : 760 : 742, in which x = 527.2.

Since a gas undergoes such great variations in volume under varied pressures, it is necessary to state the pressure when a given volume of gas is mentioned, or, as is commonly done, to have an arbitrary standard of pressure under which all gases are supposed to be measured, when not otherwise stated. The pressure which has been adopted is 760 mm., or thirty inches of barometric pressure. This is called the **standard pressure.**

The Law of Charles.—The volume of a gas varies, not only with the pressure, but it also varies with the temperature. The hotter the gas the greater its volume, and the cooler the gas the smaller its volume; or, as this law is usually stated, **the volume of a gas under constant pressure varies directly with the absolute temperature.** This is known as the law of Charles.

All gases expand or contract equally for the same increase or decrease of temperature. A gas expands $\frac{1}{273}$ of its volume in passing from 0° C. to 1° C., or $\frac{1}{460}$ of its volume for 1° F.

Now, since a gas expands $\frac{1}{273}$ of its volume at 0° C. for every degree above zero, we may regard a gas at 0° C. as having been warmed through 273° C. In other words, 273° below zero must be regarded as the absolute zero, at which temperature all gases should be reduced to liquids, or to the smallest possible space.

If, therefore, 273° be added to the temperature of a gas, we obtain the absolute temperature, or the number of degrees it is above the absolute zero.

Bearing this in mind, the law of Charles may be stated as follows: 273 + T (the temperature of the gas when measured) : 273 + T' (the altered temperature) : : V (the measured volume of gas) : V' (the new or required volume). Or, T° : T°' : : V : V' when T° and T°' stand for the absolute temperatures.

Example.—A given volume of gas at 20° C. measured 55 c.c. What would it have measured at 0° C.?

Statement.—273 + 20 : 273 + 0 : : 55 : x, the required volume. Or, 293 : 273 : : 55 : x = 51.2. Ans.

Now, since the fraction $\frac{1}{273}$ when reduced to the decimal form becomes 0.003665, it is plain that 1 c.c. of any gas at 0° becomes 1.003665 c.c. at 1° C., 1.00733 at 2° C., and 1 + n times 0.00366 at a temperature of n° C.

Whence the formula may be stated: V', or the new volume, equals V, or the known volume, multiplied by 1 + (0.00366 × (t' — t)), in which t and t' stand for the observed and required temperatures respectively, when t' is greater than t; *i. e.*, when the change of temperature is from a lower to a higher temperature.

When t' is less than t, or when the reduction is from a higher to a lower temperature, the formula becomes $V' = \frac{V}{1 + (0.00366\,(t - t'))}$.

Since V' and V are common to these two equations, and to the one used on preceding page, for correction of gaseous volumes for changes in pressure, we may combine

the equations as follows : $V' = V \times (1 + 0.00366\,(t' - t)) \times \frac{H}{H'}$, where $(t' - t)$ is a plus quantity, and $V' = \frac{VH}{H'(1 + 0.00366\,(t' - t))}$, where the reduction is from a higher to a lower temperature. These formulæ may be used for corrections for both temperature and pressure at the same time.

Example.—A given volume of air at 740 mm. and 15° C. measured 452 c.c. ; what will it measure at 760 mm. and 0° C. ? Substituting, we have :

$$V' = \frac{452 \times 740}{760 \times (1 + (0.00366 \times 15))} = 417.2 \text{ c.c.}$$

Standard Temperature and Pressure.—Variations of temperature and pressure produce such important variations in volume that it is frequently necessary, when comparing observations, to reduce them to some standard temperature and pressure. The **standard temperature** used by most scientific men is 0° C. But 60° F., corresponding to 15.5° C., being about the ordinary temperature of the air, is sometimes found to be more convenient, and is frequently used. By **standard conditions of temperature and pressure** are usually meant, 0° C. and 760 mm. pressure.

Constitution of Gases.—Law of Avogadro or Ampere.— This law states that **equal volumes of all bodies in the state of gas, and at the same temperature and pressure, contain the same number of molecules.**

As a necessary deduction from the law it follows : (1) That **all gaseous molecules occupy the same space.** (2) That the **weights of equal volumes of any two gases are to each other as the weights of their molecules ; or, in other words, the specific gravities of any two gases must be to each other as the weights of their molecules.** This law is of vast importance to the chemist, and is considered the basis of most of the modern notions of chemistry. Although it would be out of place here to enter into such a discussion, this law is capable of mathematical proof, starting with the assumption that masses are composed of molecules in a state of motion.

Size and Weight of Molecules.—That molecules actually exist, and that they are in constant motion in straight lines within the gas, there seems to be at present little room for doubt. Various recent experiments, drawn from many sources, have given us proofs of these facts. Starting from certain well-established facts, physicists have been able to calculate the absolute number of molecules in a given space, their absolute weight, size, velocity, and the spaces between two neighboring molecules. What was at first a mere hypothesis is fast becoming a demonstrated fact.

According to these calculations, a cubic centimeter of air contains twenty-one tril-

lions of molecules; and according to the law of Avogadro, all other gases must contain the same number in the same volume. Ten trillions of air, or 144 trillions of hydrogen molecules, will weigh one milligram. The mean velocity of the molecule of air at 0° C. (32° F.) is 485 meters (1591 ft.) per second; and of a molecule of hydrogen gas is 1844 meters (6050 ft.) per second. Of course, with this inconceivable number of molecules in the small space of one c.c., and all moving at the velocity mentioned, no one molecule could move long in one direction without colliding with another molecule. The number of shocks that each molecule receives, in the case of hydrogen gas, has been calculated to be 9480 millions per second, while the mean distance a molecule moves in its path before colliding is about 0.0001855 mm., which may be taken as the distance between two molecules. The diameter of the water molecule = 0.00000044 mm. Free path = 0.0000649 mm. Although these numbers give us no real conception of the magnitudes they represent, they are given here to show the tendency of research and the advances being made. These numbers apply to gases only.

Radiant Matter.—When the pressure is removed from gases the molecules are allowed to go farther apart; and while the distance between the molecules of air at the ordinary atmospheric pressure is a little less than a ten-thousandth part of a millimeter, it may reach several centimeters when the pressure is reduced by a vacuum pump to a millionth of an atmosphere. Such a rarefied gas has new properties, and has received the name of **radiant matter**, by Mr. Crookes. Under the influence of a ray of light, heat, or an electric discharge sent through the rarefied gas (pressure one-millionth of an atmosphere), the charged molecules, in the case of electricity, seem to launch forth in a direct line from the negative pole toward the positive. If a light disc be placed in this path, it is bombarded by the molecules on the side presented to the negative pole, and thus it receives a sufficient impulse to render the motion visible to the eye.

The radiometer (Fig. 4) consists of a glass globe as completely exhausted of air as possible, containing a vane holding four discs of mica, blackened on one side, and delicately suspended upon a point, so as to revolve with as little friction as possible. On bringing the globe into a strong light or near a source of heat the vane begins to revolve, because of the bombardment of the discs. The dark surface moves in the path of the light.

Diffusion of Gases.—If two gases be brought in contact with each other by inverting one jar over the other, as represented in figure 5, the gases will not long remain separate, but will quickly mingle so as to make a uniform mixture throughout both jars. This property of gases is called **diffusion**. The diffusion of gases will also take place if they are separated by a porous wall of earthenware, stone, or parchment, by the passage of the gas through the pores. A convenient method of illustrating this phenomenon is to take an unglazed earthenware cup, such as is used in a Bunsen's battery cell, invert it in a funnel

provided with a long stem, and fasten it in place by a paste made of
plaster-of-Paris. The lower end of the funnel tube is passed through a
doubly-perforated cork into a bottle containing water, as shown in the
accompanying figure. (See Fig. 6.) On bringing a bell-jar of
hydrogen or illuminating gas over the porous cup, the air in the
funnel will be forced out below, and may be seen to escape in bubbles
through the water.

Graham's Law of Diffusion.—According to this law, the
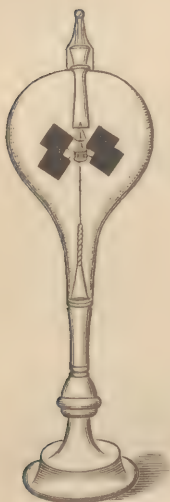
FIG. 4.   FIG. 5.   FIG. 6.

**velocity of diffusion of different gases is inversely propor-
tional to the square roots of their densities.** As an illustration
of the truth of this law we may compare the rates of diffusion of hydro-
gen and oxygen. By measurement it has been found that hydrogen
diffuses four times faster than oxygen. Their densities are known to
be 1 and 16; and the square roots of these numbers are 1 and 4. It
will thus be seen that the rates of diffusion are inversely as these last
numbers.

The phenomena of diffusion admit of easy explanation on the assumption that the molecules of gases are in a state of rapid motion. Moreover, it is plain, since a given volume of all gases contains the same number of molecules, at the same temperature and pressure, that the moving power of all molecules under these conditions must be the same; for the pressure brought to bear on the gas is balanced by the impact of its molecules, or its elasticity. To produce the same effect against the walls of the vessel, lighter molecules must move faster than the heavier ones, and more impacts occur in a given time. If M be taken as the weight of a given molecule and V its velocity, MV will express its momentum. But the pressure depends not only on the momentum of the molecules, but on the number of blows delivered by each molecule in a given time, which will depend upon the velocity of the molecules. Hence, $MV \cdot V$ will represent the pressure of the gas. Suppose this pressure be some constant unit of pressure, say the pressure of the air, represented by 1. Then $MV^2 = 1$, and $V^2 = \dfrac{1}{M}$, or $V = \dfrac{1}{\sqrt{M}}$. Now M, which represents the weight of the molecule, also, according to Avogadro's law, represents the density of the gas in question.

The above formula may therefore be written:

$$V = \frac{1}{\sqrt{D}} \text{ instead of } V = \frac{1}{\sqrt{M}}.$$

For any two gases the velocity of whose molecules are represented by V and V', we should have the following statement:

$$V : V' :: \sqrt{D'} : \sqrt{D};$$

which, stated in words, becomes: *The velocities of diffusion of any two gases* (the velocities of their molecules) *vary inversely as the square root of their densities,* which is Graham's law. The densities of hydrogen and oxygen are known to be 1 and 16, respectively, and, therefore, the velocities of their molecules must be as the square roots of these numbers, or as 4 to 1; or the molecule of hydrogen must move four times as fast as that of oxygen. The comparative velocities of other molecules may be calculated in the same way—from their densities.

HEAT.

Nature of Heat.—As nearly as we can conceive, the phenomena and sensations to which we apply the term heat are the manifestations to our senses of the motion of the molecules of matter partially discussed in the last sections. Besides producing the sensation of heat, it acts variously on bodies; it boils water, melts iron, makes the metals give out light, electricity, etc.

It was formerly supposed that heat was a form of matter—a subtle fluid which could flow from one part of a body to another or through the air. We still retain some of the forms of expression used while that theory was held, such as conduction, convection, absorption, emission, radiation, etc., the theory itself being entirely abandoned. We now regard heat as a manifestation of one form of mo-

lecular motion.   The more rapid the motion of the molecules of any
given body, the higher the temperature.

Many of the phenomena of heat may be beautifully illustrated by means of a ball
attached to an elastic india-rubber string held in the hand.   The ball may represent
the molecule; the string, the elastic cohesive force which acts between molecules;
and the force applied by the hand to make the ball revolve about it, the force of heat.

The **sources of heat** are the sun, the stars, the interior of the
earth, chemical action, and the conversion of chemical or molecular
motion into heat.   The earth receives but about two thousand mil-
lionths of the heat of the sun, and the fixed stars are estimated to furnish
about four-fifths as much as the sun.   The amount of heat annually
received from the sun would melt a layer of ice 101 feet thick sur-
rounding the earth.   The internal heat of the earth has some effect upon
our temperature, but not a very important one, as the crust of the
earth does not conduct heat well.   Chemical action is the most
important artificial source of heat.   When the heat thus produced is
intense, and accompanied by light, the bodies are said to burn.   The
heat produced in an ordinary fire is due to the chemical action going
on between the oxygen of the air and the carbon and hydrogen of
the fuel.   Animal heat is largely due to a similar cause—that is, to
chemical action going on in the muscles, glands, brain, and, in fact,
all the tissues; not, as formerly taught by Liebig, by direct com-
bustion of the food by the oxygen of the air, but by oxidation of the
different tissues whenever they are called upon to exercise their func-
tions.

Mechanical force may be converted into heat, as when the axle of a
railroad coach becomes hot, or when the brakes are applied to the
wheels, or when a piece of steel strikes a piece of flint.   These phe-
nomena may be imitated with the ball and string above mentioned,
by allowing some one to strike the ball while it is swinging, so as to
drive it faster on its course.   This is what takes place when the steel
comes in contact with the flint.

Mechanical Equivalent of Heat.—There is an intimate rela-
tionship between heat and mechanical motion.   They are capable of
being converted, the one into the other.   The friction of the match
against a roughened surface produces enough heat to ignite it.   Heat,
on the other hand, is converted into motion by the expansion of
steam, which drives the steam-engine.   It has been determined that
a certain amount of heat has its exact equivalent of work.   The unit
of work is the foot-pound—the power required to raise one pound one
foot high—or the kilogrammeter.   The unit of heat is the heat
necessary to raise one pound of water from 0° C. to 1° C. The unit of

heat now almost universally used in chemical and physiological work is the *calorie*, or the heat consumed in raising one kilogram of water from o° C. to 1° C. This amount of heat, if it could all be made to do mechanical work, would be sufficient to raise 3077.6 pounds one foot high ; or the calorie is equivalent to 3077.6 foot-pounds, or 425.5 kilogrammeters. If we adopt as the thermal unit the heat necessary to raise one pound of water from o° C. to 1° C., it is equal to 1399 foot-pounds.

Effects of Heat.—One of the first effects of heating a body is to expand it. This is the effect of heat upon all bodies, with a few apparent exceptions. Silver iodide is a notable exception to this rule. To understand just what takes place when heat expands a body, let us return to our ball and string (p. 32) ; the more force we apply to it from the arm, the more rapidly the ball will move ; as it does so, the more it stretches the string and the larger the arc it describes. If we apply enough force the string will break, and the ball will fly off into space. (Compare p. 24.)

Melting and Freezing Points.—When heat is applied to the molecules it drives them faster through their paths, and farther from one another, until finally the cohesive force is stretched to its utmost and is on the point of breaking ; then the body melts and becomes a **liquid**, in which state the two forces are nearly equal, with cohesion slightly predominating. The temperature at which a body, usually solid, passes into a liquid state is called its **melting point.** If more heat be now applied, the cohesive force (represented by the elastic string above) gives way, the molecules begin to fly off into space, and we say the liquid boils or passes into the **gaseous state.** If the heat is abstracted from a body that ordinarily exists in a liquid state, cohesion more and more overcomes the heat force between the molecules until the body contracts and passes into the solid state. The temperature at which this takes place we call the **freezing point** of the body.

Boiling Point of Liquids.—The temperature at which a liquid in an open vessel gives off vapor rapidly from the whole liquid, is constant for that liquid, and is called its **boiling point.** In giving a description of a liquid the boiling point is usually given. The boiling point of water is 100° C. (212° F.), and is nearly constant when boiled in an iron vessel in the open air. It is slightly higher in a glass or other vessel with polished walls, because the steam adheres to such a surface until it becomes a little above that point, or is slightly superheated. The pressure exerted upon the surface of the liquid may cause the temperature of the boiling point to vary, by resisting the expansive force of the molecules and aiding cohesion to keep them

together. When considerable pressure is brought to bear upon a boiling liquid its temperature rises until the tension of the steam overcomes this pressure, and it becomes **superheated**. Conversely, if the pressure be removed or lessened, the temperature at which the liquid will boil is lowered. This may be illustrated by the experiment known as the **culinary paradox**, as follows :
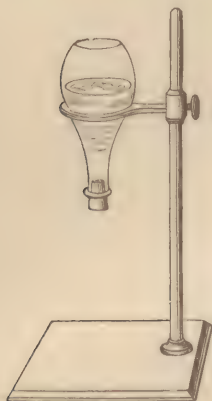
> Take a flask of water, and after boiling it vigorously for a few minutes, so that the rising steam may expel most of the air, cork it up with a tightly fitting cork, when the boiling will cease; remove the lamp and turn the flask bottom upward. (See Fig. 7.) By pouring cold water on the flask the steam is condensed, the pressure is removed from the water, and it boils vigorously. Now allow the steam to fill the flask above the water, and it again ceases boiling. A dash of cold water will again make it boil. This may be repeated until the water becomes cool enough to be held in the hand with comfort.

FIG. 7.

The boiling point of water varies, then, with the height of the barometer or the pressure of the atmosphere upon it. As the height of the barometer diminishes in ascending from the surface of the earth, the boiling point of water must fall. An ascent of about 1080 feet lowers the boiling point of water 1° C. By this means the height of mountains may be determined within a few feet. When a liquid passes off into vapor, it is said to **evaporate**. Evaporation from liquids takes place slowly and imperceptibly at temperatures below their boiling points. In the case of water, for example, there is some evaporation even from the surface of snow and ice. The moisture of the air, from which clouds, rain, snow, dew, etc., are formed, is carried up by this imperceptible evaporation from the oceans, lakes, and rivers.

Distillation and Sublimation.—When a liquid is rapidly evaporated and condensed again by means of cold, the process is called **distillation**. When water containing solid matters in solution is evaporated, the solids remain in the vessel while the water only is given off. By reason of this fact we are able to prepare perfectly pure water by distillation. When a mixture of two or more liquids is heated, that having the lowest boiling point begins to evaporate or distil first, leaving the others behind. During the rapid evaporation of a liquid, its temperature remains nearly constant at the boiling point until it is all evaporated. To separate a mixture of liquids having different

boiling points, it is only necessary to heat the mixture until that having the lowest boiling point begins to boil, and allow it to remain at that temperature until it has all passed over and been condensed. The condenser is now removed and another attached; the temperature is now raised until another portion of the mixture begins to distil over, and so on until the liquids are separated. The first process seldom effects a perfect separation, owing to some heavier liquids being carried over by the lighter ones; a second or even a third distillation is often necessary. The above process is called **fractional distillation.**

By the term **destructive distillation** is meant a distillation, usually of dry substances, so as to destroy them and obtain liquids or gases; as, for example, the distillation of coal for the purpose of preparing illuminating gas and liquids to be used for various purposes,
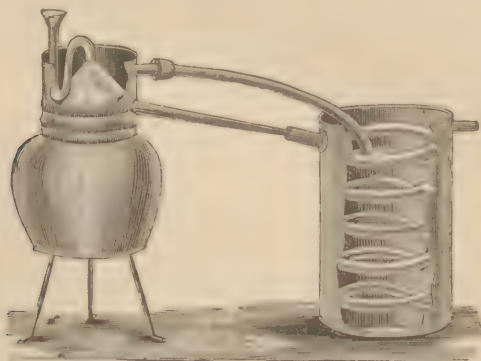
FIG. 8.

and the distillation of wood to prepare vinegar, wood-spirit, etc. Distillation is carried on in a retort or still, and the vapor is condensed in a worm or condenser. The retort or still is the vessel in which the liquid is heated, and is made of glass, copper, iron, or platinum. (See Figs. 8 and 52.)

The heat is applied to the retort or still until the liquid boils. The vapor from the boiling liquid passes through the beak of the retort into the condenser, which is always kept cool by means of cold water.

A few solid bodies when heated, do not melt and form liquids, but pass directly into the state of vapor. Such bodies are said to **sublime,** and the process is called **sublimation.**

Iodine, sulphur, camphor, and ammonium chloride are examples of

bodies which may be sublimed, and this process is usually employed for their purification.

Latent Heat.—It is evident that a part of the heat force applied to a body is used up in overcoming the force of cohesion and in expanding the body, and does not appear in the actual moving power of the molecules. In our ball-and-string illustration (p. 32), a part of the force applied to the string by the hand is expended in stretching the string, or finally in breaking it, and does not appear in the moving power of the ball. This force, which is expended in overcoming cohesion, and in keeping the molecules apart, does not appear in the temperature of a body. When air is heated and allowed to expand, about two-sevenths of the heat force is used up in expanding it. If we apply heat to a vessel containing ice, the temperature of the water formed is the same as that of the ice, although considerable heat has been absorbed in the melting process.

When water is boiled in an open vessel it does not rise above 100° C. (212° F.), however hot the fire; it remains at 100° C. until it is all evaporated. What has become of all the heat applied to the water? It has been used to drive the molecules farther apart, and is locked up in the water in the first case, and in the steam in the second. The heat thus expended is called **latent heat. It requires heat to convert a solid into a liquid or a liquid into a gas.** The reverse is equally true, that **heat is given out when a gas becomes a liquid or a liquid becomes a solid.** Freezing mixtures are based upon this law. Salt and ice form a freezing mixture, because the salt melts the ice by its affinity for water; but heat is absorbed by a solid when it becomes a liquid, and is taken up in this case from whatever happens to be in contact with the freezing mixture or vessel containing it. Ice machines operate on the principle that when a liquid evaporates it absorbs large quantities of heat. A very volatile liquid may be made to evaporate rapidly by placing the vessel containing it under the receiver of an air-pump and removing the pressure from it by pumping out the vapor as fast as formed. A very low temperature is produced in this way in and about the vessel containing the liquid. Place a few drops of ether upon your hand and allow it to evaporate and you will have a very good illustration of the heat absorbed by an evaporating liquid. Mitchell obtained a temperature of —146° F. with ether and solid carbon dioxide. Vatterer produced a temperature of —220° F. with liquid nitrous oxide and carbon disulphide.

Specific Heat.—When equal weights of two given bodies are exposed to the same source of heat they do not both rise in temperature with the same rapidity; that is, it takes more heat to raise a

pound of water from 0° C. to 1° C. than it does to raise one pound of mercury through the same change of temperature. The relative amount of heat required to raise equal weights of substances through equal degrees of temperature is called their **specific heat.** Water has the highest specific heat of any known substance except hydrogen gas. The unit of heat is not everywhere the same. Some use as the unit of heat the heat required to raise one pound of water from 32° F. to 33° F., others from 0° C. to 1° C. The latter is the one most commonly used, and is called the **thermal unit.** In France the unit is the **calorie,** which is the heat required to raise one kilogram of water from 0° C. to 1° C. One calorie = 2.2 thermal units. One thermal unit = 0.45 calorie.

Temperature.—From the preceding article it will be seen that the temperature of a body is entirely distinct from the amount of heat it contains. Temperature may be defined as the tendency a body possesses of imparting heat to surrounding bodies. It is this tendency which gives to our senses the impression that the body is **hot** or **cold**; it is, therefore, the measure of its **sensible heat,** or heat that is appreciable to our senses. The heat which a body contains is made up of its sensible heat plus its latent heat. The temperature of a body is increased or diminished by adding to or withdrawing from it sensible heat. As the number and weight of the molecules of a given body are constant, the variations of temperature must mean a variation in the velocity of the moving molecules. In our ball-and-string illustration it will be indicated by the velocity of the ball in its path.

Thermometers.—Temperature is measured by an instrument called a thermometer. Thermometers are usually constructed of a closed glass tube, provided with a bulb at one end containing a liquid whose expansion or contraction is used to indicate the temperature. It is also provided with a scale to mark the amount of contraction or expansion taking place in the liquid. Liquids are usually chosen, as solids expand too little and gases too much to be convenient. The liquids commonly used are mercury or alcohol; of these, the former is most extensively used, because of the long range of temperature between its freezing and boiling points. Pyrometers are instruments for measuring very high temperatures, and are constructed of metal or fire-clay, whose melting point is very high.

The thermometric scales in common use are the Fahrenheit, Celsius or Centigrade, and Réaumur. The difference in these scales may be seen at a glance by reference to figure 9. There are two fixed points in all of them—the temperature of melting ice and that of the steam from boiling water. These two points must be determined by actual

trial on every instrument; these points are marked on the glass with a
file or diamond. It then remains only to divide the space between
them into a certain number of degrees, according to the scale
adopted. In the Centigrade or Celsius and in the Réaumur the
freezing point of water is marked o°, while in the Fahrenheit it is
marked 32°.

The point at which the mercury rises in the tube when the latter is
plunged into steam from boiling water is marked 100° in the Celsius,
212° in the Fahrenheit, and 80° in the Réaumur. It remains, then,
simply to divide the space between these points into 100 equal parts
in the first, 180 in the second, and 80 in the third. Chemists gener-
ally have adopted the Centigrade scale, although some still adhere to
the Fahrenheit, which is in common and almost universal use in this
country for unscientific purposes. The Réaumur is not much used in
this country, and we shall not use it in this book. It is not difficult
to change the readings from one to the other scale.

It will be seen that 100° C. $=$ 180° F., 1° C. $=$ 1.8° F., or 1° C.
$= \frac{9}{5}$° F., and 1° F. $= \frac{5}{9}$° C. We must remember, however, that
the o° mark in the Fahrenheit scale is 32° below that of the Cel-
sius; hence, in converting degrees F. to degrees C. we must first
take from the reading 32°, and reduce only those above the freezing

	Centigrade.	Fahrenheit.	Réaumur.
Mercury boils, ...	350° . . .	662° . . .	280°
Water boils, ...	100° . . .	212° . . .	80°
Water freezes, ...	0°	32°	0°
	—17.7° . .	0°	—14.2°
Mercury freezes, ...	—40° . . .	—40° . . .	—32°
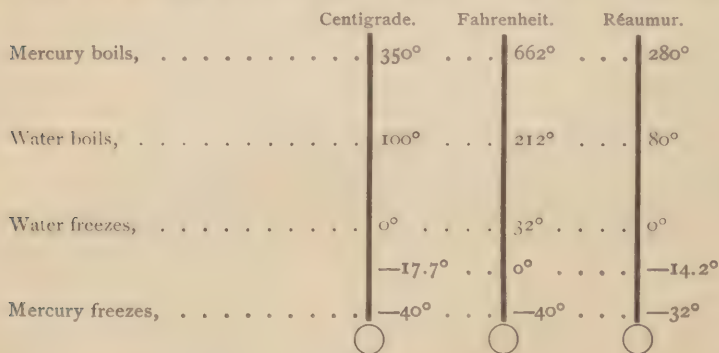
FIG. 9.

point of water. While in changing degrees C. to F., we must add
32° to the result to obtain the true reading.

Thus, 10° C. $=$ 10 $\times \frac{9}{5} =$ 18 $+$ 32 $=$ 50° F.; and 41° F. $=$ 41 $-$ 32 $=$ 9 $\times \frac{5}{9} =$
5° C. Or, multiply degrees C. by $\frac{9}{5}$, and add 32 $=$ degrees F.; and multiply de-
grees F. by $\frac{5}{9}$ after subtracting 32 $=$ degrees C.

The Centigrade and Fahrenheit degrees will both be given in this
book.

LIGHT.

The second so-called physical force which plays an important part in many chemical phenomena is light. According to the best conception we have of light, it is the effect upon the optic nerve produced by undulations of an exceedingly subtle and highly elastic form of matter, called the **luminiferous ether**. That this ether really exists, pervading the spaces between the molecules of all bodies, and being many million times more elastic than air, and so light that it offers no appreciable resistance to the earth moving 1100 miles a minute through it, is merely a hypothesis. It has been advanced to explain certain well-known facts. That light passes from the sun and stars to the earth, no one can doubt; and yet, without some assumption like the above, we can not conceive how it does so unless we hold to a former view, which taught that light is in itself a form of matter, without weight, given off by luminous bodies, and able to pass through glass, water, rocks, etc. These properties are contrary to all known laws of ordinary matter, as also are those of the ether assumed in the other theory.

It is believed that undulations may originate in certain motions of molecules or atoms; that these motions or undulations are communicated to the ether and conveyed upon it in the form of waves; and that the movement described by a given particle of ether is, in the main, an oscillation at right angles or perpendicular to the direction of the ray or beam.

Transmission of Light.—The motion of a ray of light travels along the line of particles very much in the same way that it passes along the line of ivory balls placed in contact on the billiard table when a ball strikes the end one directly in line with the rest. The motion or impulse passes along the line, but the ball at the opposite end is the only one seen to move. The transmission of force may be illustrated by placing a ruler on the table, holding it firmly in place, with a marble in contact with one end, and with a hard body striking a short, quick blow at the other end. The stick, as a whole, does not move, but the jar will be felt to pass under the hand and the marble will move from its place.
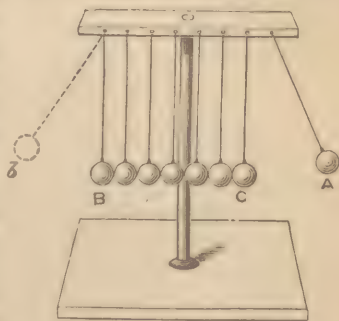

FIG. 10.

A frequent class-room illustration of the transmission of force is that represented in figure 10. A number of wood or ivory balls are suspended by cords so that they

touch one another when at rest. On raising A to the position represented in the cut, and allowing it to fall against the ball C, none of the balls are seen to move except B, which is carried on to the position *b*. As it returns to strike its neighbor, the ball A is thrown off to a less distance than it was at first carried. The other balls remain at rest, but transmit the force along the line.

Color and Intensity.—It is evident that these oscillations may differ in rapidity or in their amplitude—*i. e.*, comparing them to the movements of a pendulum, they may vibrate rapidly or slowly, and they may swing a long or a short distance. Upon the extent and rapidity of these oscillations depend two important differences in the effects of light on the organs of vision—viz., color and brilliancy; the brilliancy depending upon the force of the blows upon the retina, and the color upon the number in a given time. We have an analogous fact in sound. Here we can more easily demonstrate the truth of the fact that the intensity of the sound depends upon the amplitude of the vibrations of the molecules, while the pitch depends upon the number of waves or pulsations which reach the ear in a given time. From well-established data we are able to calculate the rapidity of the oscillations which produce the different sensations of color, and the corresponding lengths of the ether waves. Some of these results are expressed in the following table:

Color.	Length of Waves in Fractions of a Millimeter.	Number of Oscillations in One Second.
Red,	650 millionths.	477,000,000,000,000
Orange,	609 "	506,000,000,000,000
Yellow,	576 "	535,000,000,000,000
Green,	536 "	577,000,000,000,000
Blue,	498 "	622,000,000,000,000
Indigo,	470 "	658,000,000,000,000
Violet,	442 "	699,000,000,000,000

The color of an object depends upon the character of the light it reflects or transmits to the eye. A beam of white light is composed of a variety of different colored lights mingled together, as can be shown by passing it through a prism of glass having an angle of 60°, by which it is decomposed into its component colors. When a body looks red to us, it is because it absorbs or destroys all the oscillations of the white light except those which give us the sensation of redness. If it be blue, only the vibrations that give us the sensation of blue light are reflected. Some bodies and solutions reflect one color and transmit another. The color transmitted is usually the complement of the one reflected—*i. e.*, if the two lights are mixed together they produce the sensation of white light. If a solution of nickel salt and one of cobalt are cautiously mixed, the color of the one mixes

with that of the other so as to form a colorless solution, because the colors are complementary.

The Spectrum.—When a beam of white light is passed through a prism, as represented in figure 11, it is not only refracted,—that is, bent from its original course,—but the colors of which it is composed, being unequally bent, are separated from one another. If now we allow them to fall upon a white screen (S, Fig. 11), they produce a series of blending tints upon it, which are called a spectrum.

The red rays, which are least bent from their course, are said to be the **least refrangible,** while the violet are the **most refrangible.** Intermediate between these colors we find the orange, yellow, green, blue, and indigo. The prism thus gives us an easy means of analyzing a beam of light, to show the character of the rays producing it. Such observations are usually conducted by means of an instrument called a spectroscope (Fig. 12).
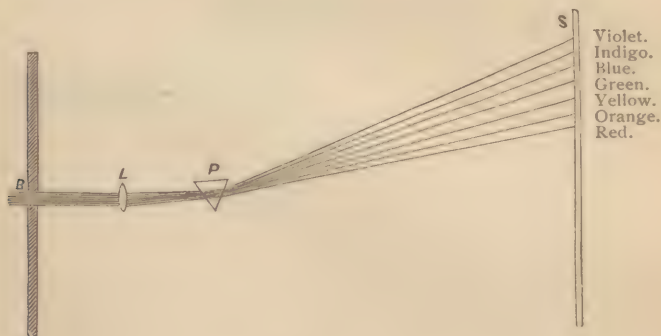
FIG. 11.

The Spectroscope.—Figure 13 will illustrate the construction of the spectroscope. The light is received from the source of light through a very narrow slit (S), regulated by a screw ; it passes through the tube (A), called the collimator, and is directed through the prism (P), which may be made of flint glass, or it may be made hollow and filled with bisulphide of carbon. In some instruments there are several flint glass prisms, so arranged that the light is made to pass through all of them, so as to secure a wider dispersion of the rays than can be obtained with one prism. The beam of light, after traversing the prisms, is viewed with the telescope at (B). For purposes of comparison, an additional tube (D) is attached, by which another light may be thrown upon the surface of the prism so as to be reflected

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FIG. 12.—SINGLE PRISM SPECTROSCOPE.
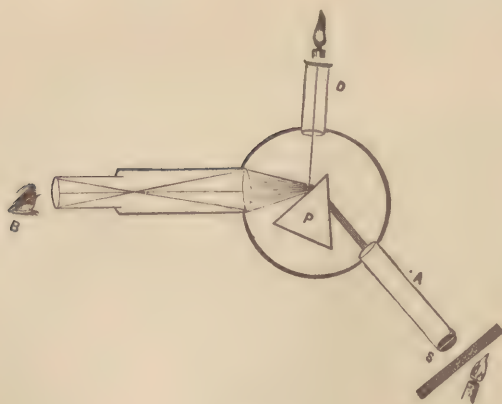
FIG. 13.

through the telescope by the side of the light from (S).* Many instruments now made are so arranged that the ray of light in passing through the prism is not bent from its course, and these are called **direct vision spectroscopes.**

Bright Lines.—When we view **monochromatic** light with the spectroscope,—that is, a light composed of but one color,—we see only a vertical image of the slit at B, and its position will depend upon the refrangibility of that color. If, on the other hand, we illuminate the slit with a light containing several rays of different degrees of refrangibility, we shall see one image for each ray present; and they will be separated from one another by their differences of refrangibility. The same color always appears in the same position with reference to the others. If we look at a solid body, heated till it emits a pure white light, there are so many images spread out on the field of vision that one overlaps another until there are no dark spaces between them, thus producing a **continuous spectrum,** as it is called. If we place a light before the slit which emits very little light of its own, such as that given by a Bunsen burner, and then put into this flame a little sodium, which gives a pure yellow light, we shall see but one image of the slit, and that in the position occupied by the yellow in the continuous spectrum or the D line in the solar spectrum. If we use lithium instead of sodium, we get one image in the position occupied by the red; if thallium be used, the single image is seen in the position of the green. If we mix the three, we shall see the three images as bright lines, each in its own position—one in the yellow, one in the red, and one in the green. In the best instruments the yellow sodium line appears as two parallel lines. If we illuminate the slit with the vapor of a metal which emits rays of several different degrees of refrangibility, we shall see several images, or bright lines, in different portions of the field. Any given element always emits the same rays under like conditions; hence, by the use of the spectroscope, we may determine by the lines we see in the telescope what element is introduced into the flame of the lamp.

Solar Spectrum—Dark Bands.—If we illuminate the slit with the light of the sun, we see almost a continuous spectrum, marked by a number of dark lines, known as "Fraunhofer's lines," the cause of which we shall refer to again.

The most prominent of these dark lines have been designated by the letters of the alphabet, as will be seen on reference to the solar spectrum in the frontispiece. These lines serve as landmarks upon the spectrum, by which we can fix the position

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* For an explanation of the principle of lenses the student is referred to works on physics.

of other lines, or by which we can designate the position of any line. The D line, for example, is the most brilliant, and can always be seen in the solar spectrum. This serves as a starting-point in mapping the spectrum, or as a guide in focusing or adjusting the telescope.

Spectrum Analysis.—The spectroscope is an important aid to chemical analysis, when used with certain precautions, and with certain well-known facts in its use kept in mind.

The principles upon which spectrum analysis is founded are as follows :

1. All bodies, when intensely heated, become luminous.

2. Solid and liquid bodies, if opaque, emit when heated first a red light, and as the temperature rises the other colors make their appearance, and mingle with it until all the colors are present and produce white light. If the temperature reaches what is called a blue heat, the blue and violet rays begin to predominate.

3. The elementary substances give their characteristic and peculiar light only in the state of gas or vapor. Hence, when we examine the light from any given source, we conclude, if the spectrum is continuous, that the heated substance is a liquid or a solid, while if the spectrum is broken, that it is a luminous gas or vapor. From the position of the bright lines we determine the nature of the substance giving the light. There are, however, a few exceptions to this principle. Under certain conditions, even a gas may give off a light that produces a continuous spectrum.

4. At the temperature at which gases or vapors become luminous, compound bodies, as a rule, break up into their constituents—*i. e.*, the elemental atoms seem to be dissociated. For this reason little is known of the spectra of compound bodies.

5. At a high temperature the metallic atoms are much more luminous than the non-metallic with which they are associated. Hence, when we examine the vapor of a metallic salt rendered luminous, the light emitted is so largely that of the dissociated metallic atoms that, whatever salt of that metal be used, we obtain essentially the spectrum of the metal itself.

6. If, when the slit of the spectroscope is directed toward a source of white light giving a continuous spectrum, another flame giving a monochromatic light from a luminous vapor be interposed between the white light and the slit, a dark image of the slit will appear in the position where the vapor itself would have given a bright line ; that is, when the light from a liquid or solid luminous body is made to pass through a luminous vapor, those rays of light which the vapor of itself emits are absorbed. Hence, when we analyze the light of a distant source of light, and observe a continuous spectrum marked by

dark lines, we may conclude that it is produced by a solid or liquid luminous body shining through a luminous vapor. This explains the dark lines seen in the solar spectrum. They teach us that the sun is a solid, intensely luminous body, surrounded by a luminous atmosphere.

7. Many substances in solution absorb certain rays from a beam of white light passed through them, and the portions of the spectrum absorbed are peculiar to each substance. We thus have a means of detecting the presence of a few substances which can not be rendered luminous, by passing a white light through the solution suspected to contain them.

Absorption Spectra.—When we wish to observe the spectrum of a liquid we place it in a glass tube or, preferably, a vessel having parallel sides, and place this before the slit of the spectroscope. We now throw a strong white light through the solution and into the slit of the instrument. Solutions of **erbium** and **didymium** examined in this way absorb certain portions of the spectrum given by the source of light. The particular portions of light absorbed are peculiar to each, and in these cases the dark bands across the bright spectrum occupy the same positions in which the vapors of these elements give light bands. Absorption bands differ from the dark lines of the solar spectrum in being broader and not so sharply marked. They are often only a slightly darkened portion of a bright spectrum. Passing the light through a crystal of the substance, in some cases, gives the same result as passing it through its solution.

The use of the spectroscope in medicine and toxicology is chiefly confined to the observation of absorption spectra of various solutions. Some idea of the appearance of such spectra may be obtained by reference to the frontispiece, remembering that the spaces which appear white there, are in practice occupied by the colors of the solar spectrum in their appropriate places.*

Chemical Effects of Light.—If a mixture of pure hydrogen and chlorine gases be prepared in the dark and kept there, no combination takes place; if the mixture be brought out into a light room, a gradual combination takes place, and hydrochloric acid is the result; if the mixture be placed in the direct rays of the sun, instead of diffused light, the combination takes place with an explosion. The light in this case causes chemical action. The electric light and other intense lights produce the same effect. If a piece of white paper wet with a solution of nitrate of silver be kept in a dark room, no change takes place in it; but if the paper be exposed to a strong light, it begins to grow dark, and finally becomes black.

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* See Rosenberg or McMunn on the use of the spectroscope in medicine.

Many chemicals kept in the light are in time sensibly changed. Silver and gold solutions, in presence of organic matter, deposit a part of their metal in the metallic form. Nitric acid becomes slowly yellow from the decomposition produced by the light. A solution of the syrup of the iodide of iron, on exposure to air becomes brown from decomposition; but on exposure to the direct sunlight it again recombines and returns to the normal green color. The art of photography is based upon the changes produced by light in silver salts, gelatin, etc. Sometimes the change seems to be a true chemical reaction, and in other cases it is a molecular change only.

It has been found that it is not always the luminous part of the ray of light that effects these changes, but that they are chiefly produced by certain invisible rays found most abundantly in and beyond the violet part of the spectrum. From this it has been concluded that the light of the sun, as well as the light from some other sources, contains certain rays having this power to produce chemical changes, but which do not affect the eye to give the sensation of light. This action of light is known as **actinism**, and the rays producing it are called **actinic rays.**

The heat rays which accompany the light rays in an ordinary beam of light are less refrangible than the latter, and are therefore found principally in the orange, red, and ultra-red portions of the spectrum.

We thus have three kinds of rays in the solar spectrum :

I. The heat rays extend from without the red to the line F (see frontispiece), being most intense at A, or in the red.

II. The light spectrum extends from A to H, being most intense between D and E.

III. The actinic rays, found from E to some distance beyond the violet, and being most intense at H.

Polarization of Light.—Ordinary light, according to the wave theory, is due to vibrations of the luminiferous ether occurring in all directions or planes at right angles to the path of the ray.

A ray of light is said to be plane polarized when these vibrations are so changed as to occur only in one plane. This change in the vibrations may be produced by passing the ray of light through certain crystals, such as Iceland spar, selenite, quartz, etc., or by reflection from a glass plate placed at an angle of $35°\ 25'$ to the path of the ray, or from water at an angle of $52°\ 45'$.

We may illustrate the effect of polarization upon a ray of light, roughly, by a string stretched between two points, A and B, figure 14. If we touch the string with the finger it is free to vibrate in all directions—up and down, side to side, or in any intervening plane. If now we place over the center of the string a piece of cardboard, C, figure 15, with a long slit cut in it, and then cause the string to vibrate, the vibrations will be limited to the direction of the length of the

slit in the card. This may serve to illustrate the effect of a polarizing crystal upon a ray of light.

If in this experiment a second piece of cardboard be employed, so held that the slit is in the same position as the first, no interference with the vibration will take place. This cardboard may serve to rep-
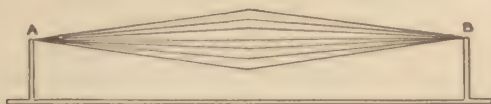
FIG. 14.

resent a second section of a crystal through which the light is made to pass.

If while the string is vibrating the second piece of cardboard, D, is made to revolve through 90°, so that the slit in this card is at right angles with that in the first card, the vibrations of the string will be limited in all directions, and it will cease to vibrate.
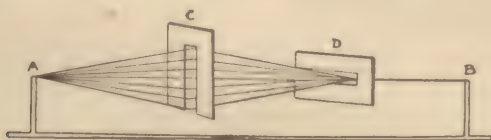
FIG. 15.

If instead of the string we use a ray of light, and in place of the cardboards we use sections of a polarizing crystal, the vibrations of the ray will be limited to one direction, but continue to pass as long as both crystals are in the same relative position. If we conceive a cross-section of a ray of light magnified, we might represent the path
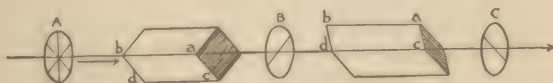
FIG. 16.

of the vibrations of the molecule by the spokes of a wheel, as at A, figure 16.

We may conceive that the molecules of the crystal are arranged in lines so that they interfere with all vibrations not in the same plane as these rows of molecules.

In the first crystal we may conceive these rows to be vertical. The light, after passing through this crystal, as shown in cross-section at B, is seen to be polarized in the vertical plane—*i. e.*, the vibrations of the particles of ether are reduced to one plane.

If a second crystal be interposed in the path of the polarized ray, and held in the same position with reference to its axes or lines of molecules as the first, the ray will pass unobstructed.

If the second of the crystals be rotated through 90°, this will interfere with the vibrations of the ray as polarized by the first crystal, and they will cease—*i. e.*, no light will pass through this second crystal. Only those vibrations can pass this crystal which take place in the plane shown in C, at right angles to those shown by B. Polarizing crystals can not be supposed to contain slits, as here indicated, but their molecules are so arranged as to sift the light that passes through them and limit the vibrations of the luminiferous ether, just as the slit in the cardboard, in our first illustration, does the vibrations in the string.

If, in the above experiment, we place the cards upon the string so that the slit in one makes an acute angle with that in the other, the string will still continue to vibrate, but it will swing through a shorter distance, which will grow shorter as the second card is rotated ; that is, the vibrations are gradually stopped as the card is turned. The same phenomena are observed with the crystals. If the crystals are placed in the same position with relation to their principal axes, the light passes freely. If one of them be rotated, the transmitted light grows gradually less and less until the crystal is turned through 90°, when almost total darkness results. There is nothing in the appearance of a polarized ray to indicate to the naked eye its peculiar condition ; but if the eye be aided by a polarizing prism, it is easy to detect the fact that it is polarized.

Double Refraction and Polarization.—If a black dot on a sheet of paper be looked at through a crystal of Iceland spar (calcite), there appear to be two dots. The ray of light in passing through the crystal to the eye is split into two rays of equal brilliancy. If the crystal be rotated, one of the dots revolves around the other. The ray that gives the stationary image is called the **ordinary ray**, while the other is called the **extraordinary ray.** Both rays are polarized, and in planes which are at right angles to each other. It is found that certain non-crystalline substances, like muscle, cilia, etc., are doubly refracting.

The Nicol prism is the prism usually employed as the **analyzer** in polariscopes. It consists of a rhombohedron of Iceland spar divided through its obtuse angles, *b, d, e, f* (Fig. 17), and at right

angles with the surface, *a*, *b*, *c*, *d*. The cut surfaces are polished and cemented together again in the former position with Canada balsam.

When a ray of light is passed into such a prism it is split into two portions—*h m*, the extraordinary, and *h n*, the ordinary ray. When *h n* meets the Canada balsam at *n*, it undergoes total refraction and passes out in the direction *n o ;* while the extraordinary ray passes through and emerges alone in a direction parallel to the entering ray. By the use of such a prism the light is completely polarized in one plane.

If a second Nicol prism be mounted in a tube so that the light may pass directly through both prisms, we have, in principle, an instrument known as the polariscope. When the two prisms, thus mounted, are in the same position with reference to their axes, the light passes
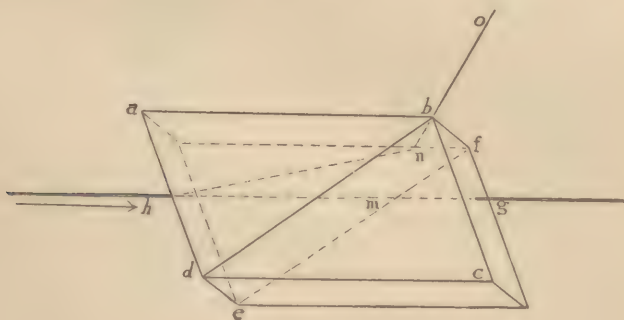
FIG. 17.

readily through both. On rotating one of the prisms to the right or to the left, the light is more and more obstructed until the prism is turned through 90°, when very little, if any, light passes through. The use made of this property of the Nicol prism will be referred to again.

Rotation of the Plane of Polarization.—Certain crystals, such as quartz, certain fluids, such as turpentine, and solutions of certain substances, like sugar and albumin, have the power of rotating the plane of the polarized ray sent through them to the right or left. Such substances are said to be **optically active.** The degrees of a circle through which the rotation occurs often serve for the accurate estimation of these bodies. This method may be used for the estimation of the sugars, turpentine, certain alkaloids, albumin, etc. The rotation produced is different for different kinds of light. White light is split into its various colors, each color being rotated differ-

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ently. White light can not, therefore, be employed for transmission through the instrument in these examinations. A monochromatic light—usually that from volatilizing a sodium salt in the flame of a Bunsen burner—is employed. This gives a bright yellow light, which is practically monochromatic.

Polarimeters or **polariscopes** are instruments for determining the strength of solutions of sugar, albumin, etc., by the direction and amount of rotation they produce in the plane of polarized light. They are sometimes called **saccharimeters**, because they are constructed especially for the estimation of sugar.

There are in the market various forms of polarimeters, but in all forms of the apparatus the polarizer, or means of obtaining a beam of polarized light, consists of the Nicol prism above described. The analyzer is composed of a similar Nicol prism, and a telescope is frequently employed as an eye-piece. The polarizer is mounted at P R (Fig. 18). The analyzer is so mounted at H that it may be rotated about its long axis, and is provided with an arm which moves upon a graduated scale, so that the degree of rotation from the zero point may be measured in degrees of the circle. A solution of the substance to be examined is placed in a tube with glass ends and brought between the polarizer and analyzer in the support L. The light, after being polarized, passes through the tube and then through the analyzer.

Laurent's polarimeter (Fig. 18) is one of the simplest and best. In this instrument one-half of the field of vision is covered by a very thin plate of quartz, which slightly rotates the plane of the light passing through it, and causes some light to pass even when the polarizer and analyzer, both of which are Nicol prisms, are crossed. If the analyzer (H) be rotated so as to cause the quartz plate to become dark, the light passes through the uncovered half of the field. In an intermediate position the two halves of the field appear equally illuminated. The scale (C) is so graduated that this position of the analyzer is made the zero point of the instrument. The slightest deviation of the analyzer from this position causes one-half of the field to appear darker and the other half lighter. There is thus presented to the eye two lights to be compared, and the instrument is thus very sensitive. Monochromatic light must be used. In some instruments the circle is divided both into degrees and sugar units, or percentages. The scale is read by means of a vernier and lens (N). Before using an instrument the observation tube is filled with water and placed in position between the analyzer and polarizer. If the instrument is properly adjusted the zero mark on the vernier will correspond with the zero point of the scale, when the two halves of the field are equally illuminated. The tube is then filled with the solution to be tested

and again placed between the analyzer and polarizer, when, if it is an active substance, the plane of the polarized ray coming from the ana-
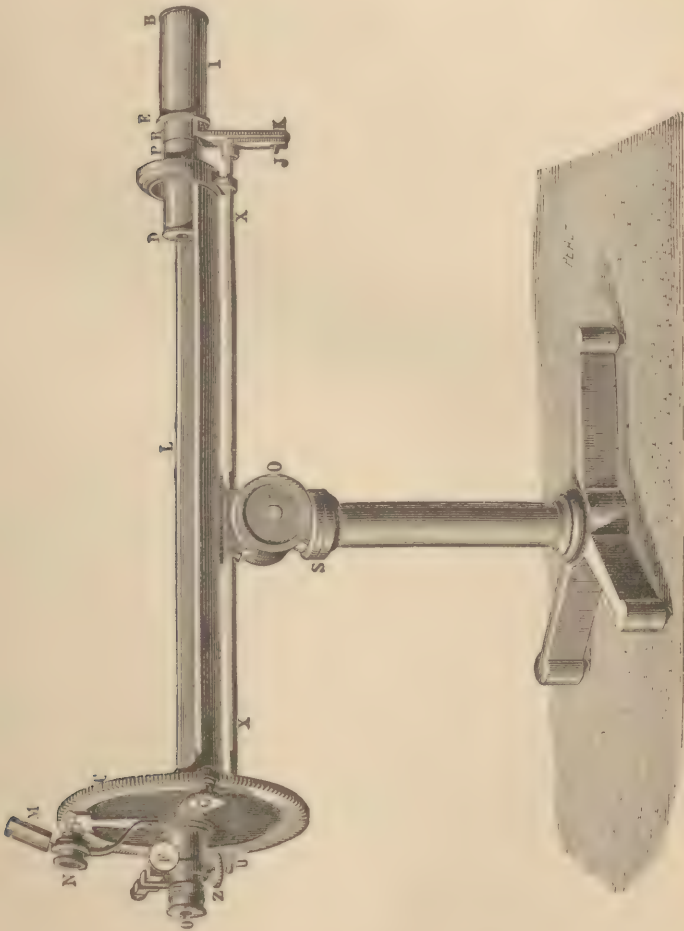

FIG. 18.—THE LAURENT SHADOW POLARIZING SACCHARIMETER.

lyzer will be turned to the right or to the left in passing through the solution, and one-half of the field will be lighter than the other. The amount of rotation of the plane of the polarized ray will be propor-

tional to the amount of the active substance in the solution.   It will now be necessary to rotate the analyzer (H) to the right or to the left, so that the two halves of the field will again appear equally illuminated.   When this has been accomplished, we may read off on the vernier the degrees of the circle through which the analyzer has been rotated.   In this way the amount of rotation of the polarized ray is determined.

The specific rotatory power of any substance is the amount of rotation of the plane of polarized light, in degrees of a circle, produced by one gm. of the substance dissolved in one c.c. of the liquid, examined in a tube one decimeter in length.   The specific rotatory power of a substance is obtained by dividing the angular rotation observed in the polarimeter (a) by the length of the tube in decimeters (l) and by the number of grams in one c.c. of the liquid (w). If a sodium flame be used as the source of light, the specific rotation of the substance is that of light, with wave-lengths corresponding to the D line of the solar spectrum, and is usually denoted by $(a)_D$. Then the above statement may be expressed as follows :

$$(a)_D = + \text{ or } - \frac{a}{w\,l}.$$

In this formula plus indicates that the substance is dextrorotatory and minus that the substance is levorotatory.   If in this formula the specific rotatory power of the substance under examination be known, and we wish to find the value of w, or the weight of the substance, then the formula becomes :

$$w = + \text{ or } - \frac{a}{(a)_D \times l}.$$

In this formula (a) is the observed rotation, (l) the length of the tube in decimeters, which is known, and $(a)_D$ the specific rotatory power, which has been determined for all well-known optically active substances : (w) can easily, therefore, be calculated.   The specific rotatory power of a few of the most important optically active substances is as follows :

Cane-sugar, $(a)_D = +$ 73.8°	Levulose, $(a)_D = -$106°
Milk-sugar, " $= +$ 59.3°	Egg-albumin, " $= -$ 33.5°
Dextrin, " $= +$130.8°	Serum-albumin, " $= -$ 56°
Dextrose, " $= +$ 56°	Gelatin, " $= -$130°

ELECTRICITY.

Electricity Produced by Friction.—If a piece of glass rod or tube, sealing-wax, resin, or sulphur be rubbed briskly with a piece of flannel or silk, it will be found to have acquired properties which it did not previously possess—namely, of attracting to itself such light objects as bits of paper, feather, or dust. After adhering to the glass rod for a few seconds these objects are thrown off again with a perceptible force. This property was first observed in amber, or **electron,** as the Greeks called it, as early as 600 B. C. Dr. Gilbert, of England, about 1600, showed that a very large number of bodies exhibit the same property, which he called **electrics.** Since his time the name **electricity** has been used to designate the agency at work to produce these phenomena. A better way of showing these phenomena is by means of a ball of elder-pith suspended by a fine silken thread. If the excited glass rod be presented to the pith-ball, the latter is attracted and then thrown off. If, now, a piece of sealing-wax be rubbed and presented to the electrified pith-ball, the latter is strongly attracted to it. In other words, a pith-ball that has been charged by the glass is repelled by the electrified glass, but is attracted by the electrified sealing-wax; or, if electrified by sealing-wax, it is repelled by it and attracted by the glass. We thus have two kinds of electricity developed by these two substances. If two pith-balls be suspended by silk threads so as to touch each other, and they are both electrified or charged by the same piece of glass or sealing-wax, they will be thrown apart and held in this position as long as they remain charged. (See Fig. 19.) If one ball be charged from glass rubbed with silk, and the other be charged with sealing-wax rubbed with flannel, they will then attract each other.

FIG. 19.

This fact is usually stated in the following law: **Bodies similarly electrified repel and bodies oppositely electrified attract one another.**

This law will be referred to again as an aid in the explanation of many other phenomena.

The kind of electricity produced in the above experiments depends not only on the thing rubbed, but also on the rubber; for glass yields the one kind when rubbed with silk and the opposite kind when rubbed with cat's skin. Resin and sealing-wax rubbed with an amalgam of tin spread on leather yield the same electricity as glass when rubbed with silk, but yield the opposite kind when rubbed with

flannel. That kind produced by glass and silk has received the name of positive ($+$) electricity; the electricity produced by resins rubbed with wool has received the name of negative ($-$). These positive and negative electricities, when brought together in a body, neutralize each other, and the body then shows no electricity at all. The electrification of either kind produced by friction or other means upon the surface of a body is called a **charge.**

The body which shows the electrical phenomena is said to be **charged.** A charge may be large or small, positive or negative. When the body is brought again to the natural condition it is said to be **discharged.** Good conductors of electricity are discharged by bringing them in contact with the ground or touching them with the hand. The discharge is usually instantaneous, and is accompanied by a snapping sound and a flash of light, called a spark, which, when received on the hand, produces a pricking sensation.

The condition of electrification is generally conceived to be a peculiar disturbance brought about in the molecules of a body or of the **ether** surrounding them. This condition or disturbance is capable of being imparted to neighboring molecules of certain kinds, but not readily to all molecules. Bodies whose molecules are readily affected by the electrical disturbance, and transmit it from one to another, are said to conduct electricity, or are **conductors;** those whose molecules do not readily take up and transmit this disturbance are called **insulators.** If, for illustration, the balls in the apparatus represented in figure 10, page 39, are made of some elastic substance, the force of the ball A is transmitted to B; but if the balls are made of loosely wound yarn, the force is not transmitted. Whether the force is transmitted will depend upon the composition of the balls. So in electricity the question of conductivity depends upon the composition of the molecules.

The metals are generally good conductors of electricity, while gases and the non-metals are poorer conductors. Electricity may either reside upon the surface of bodies as a **charge,** or it may be transmitted through their molecules as a **current.**

Electricity by Induction.—If we electrify by friction a glass globe or flask, C, mounted upon a glass support, and then bring near it, as represented in figure 20, a large sausage-shaped metallic conductor, A B, also mounted upon a non-conducting glass support, we shall find that the two ends of this conductor exhibit all the properties of an electrified body. They will attract bits of paper; and pith-balls mounted upon these ends are repelled, as shown in the cut, while the center of the conductor shows no sign of electrification. Further examination will show that the two ends show opposite kinds of electrification.

The end nearest the electrified glass will show a negative charge, while the other will show a positive charge. When the glass globe is removed, the two charges neutralize again and disappear. This influence of an electrified body upon another body near it is known as **induction.**

It appears, then, that a positive charge attracts negative and repels positive, and that this influence is exerted at a considerable distance, separating the two charges in the body acted upon as long as the inducing body continues near it. The quantity of the two charges thus separated will depend upon the quantity of the charge upon the inducing body, and its nearness to the conductor. By the quantity of a charge of electricity we mean its power of doing electrical work
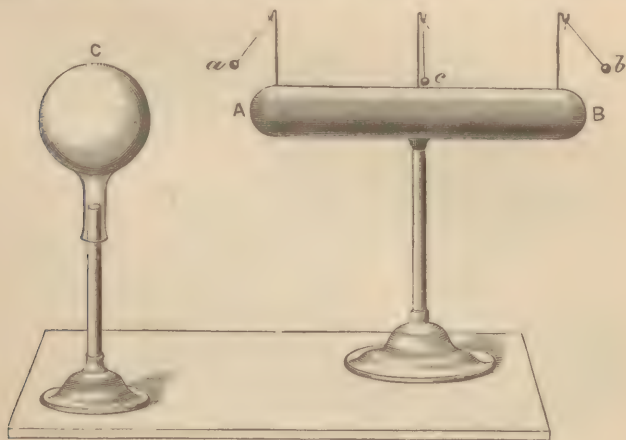
FIG. 20.

in returning to a state of equilibrium. This is more generally spoken of as its **potential.**

For example, a highly charged body, when touched with the finger, will give a long, brilliant spark or will strongly attract light bodies, while one charged with a low potential may give no perceptible spark and attract only very small bodies. A positive charge is frequently spoken of as a high potential, while the negative is referred to as a low potential.

Other Sources of Electricity.—Friction is not the only means of generating electrical disturbances. Other agencies are percussion, compression, heat, chemical action, crystallization, physiological action, contact of metals, vaporization, magnetism, etc. Indeed, it is now

known that very many natural processes are accompanied by electrical disturbance. Of the many possible ways of producing electricity, the principal ones employed to advantage are friction, chemical action, and magnetism. The first of these, combined with induction, is utilized in the so-called static machines; the second in the ordinary galvanic battery; and the third in the dynamo-electric machines, used for developing powerful currents. For medical purposes the first two kinds of machines are chiefly used at the present time.

Static Electrical Machines.—For the purpose of generating large quantities of electricity, various kinds of electrical machines have been devised. In the earlier machines a glass cylinder was used, mounted on a horizontal axis, and provided with a crank with which to revolve
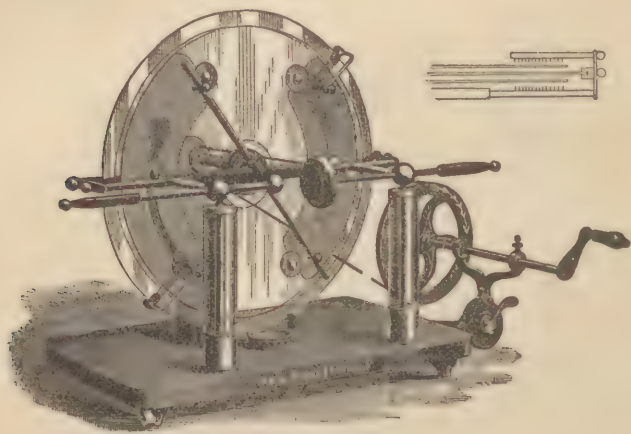
it. Upon this cylinder a rubber, made of leather dusted with tin or zinc amalgam, was pressed. The rubber was connected with the earth, while a brass comb or a row of points connected with a conductor, similar to the one represented in figure 21, allowed the positive electricity to escape from the glass cylinder to the conductor and the negative to escape from the conductor to the glass cylinder. Glass discs were then substituted for the cylinder. In the more recent machines, known as the Toepler-Holtz machines (see Fig. 21), the rubbers are dispensed with. The charge is developed entirely by induction, produced by rapidly revolving a glass plate or disc near a stationary disc bearing two armatures, one of which must contain a

small initial charge to begin with. For a detailed description of this somewhat complicated machine the student is referred to works on physics. It is so arranged that either a constant current may be obtained, giving most of the effects of the galvanic current, or inter-mittent shocks, giving the effects of the interrupted currents, or those of the electrical bath. As the potential of static electricity is much greater than that of galvanic, about to be considered, it may be applied through the clothes, and thus obviates the necessity of uncovering the part to be brought under its influence—a fact greatly appreciated by many patients.

MAGNETISM.

Properties of Magnets.—The name magnet, or lodestone, was given by the ancients to certain black, hard stones found in various parts of the world, which possessed the power of attracting to them-selves bits of steel or iron. About the tenth or twelfth century these magnets were discovered to point north and south when suspended by a thread. Natural magnets are an ore of iron, known as magnetite, having the compositon Fe_3O_4.

If a piece of hardened steel be rubbed with one of these natural magnets, it acquires the properties of the magnet, and retains those properties for a very long time. If a piece of soft iron be treated in the same way, it becomes a magnet when in contact with the mag-net, but loses its magnetic properties when the latter is removed. The

Fig. 22.

peculiar qualities of a magnet are easily shown to be manifested chiefly at the two extremities, when brought near an electrified body, as was noted in the case of the conductor A B, in figure 20. If a bar magnet be dipped into a keg of small nails and withdrawn, a large number of them will adhere to the two ends of the bar. The two ends where the magnetic force is strongest are called its poles. A light magnet, balanced at the center upon a needle-point, so as to allow free-dom of movement, is called a magnetic needle. (See Fig. 22.) Such a needle always arranges itself nearly due north and south, and always in the same position. The compass sold by opticians is simply such a needle mounted above a dial, marked with the " points of the com-pass." The end of the needle or magnet that points to the north is called the **north pole**, and the other the **south pole**. If a magnet

be broken at any point between the two poles, each of the pieces becomes a magnet with two poles ; it is therefore impossible to make a magnet with but one pole. In magnetism, as in electricity, like poles repel and unlike poles attract one another. The force with which a magnet attracts or repels another magnet or a piece of iron is called the magnetic force. The magnetic force acts through all kinds of bodies except iron or other magnetic metal, and varies inversely as the square of the distance. Iron, nickel, cobalt, cerium, chromium, and manganese are recognized as magnetic metals. Paper, porcelain, and oxygen gas are feebly magnetic. Magnetism may be induced in a piece of iron by the near presence of a magnetic pole. If iron filings be sprinkled over one end of an ordinary iron bar, and one of the poles of a permanent magnet be brought near the other end of it, the filings will be attracted by the iron bar.

The pole of the bar nearest the magnet will be found on examination to be of the opposite kind to that of the magnet ; in this respect magnetic induction resembles electrical induction. The magnet is not weakened by the induction, but rather strengthened by the reaction of the newly made magnet upon its polarity. Artificial magnets may be made into any desired form, but the usual forms are the straight bar and the horseshoe form. The latter form admits of the application of a connecting bar of soft iron from one pole to the other, known as an **armature.** When a magnet is not in use the armature should always be applied, to retain the full power of the magnet. Long, thin, steel magnets are stronger in proportion to their weight than thicker ones ; consequently, strong magnets are frequently made of a number of long, thin magnets bound together after being magnetized.

Electromagnets. — Heretofore we have spoken of but one method of making a magnet, that of contact with another magnet. If a bar of iron be thrust into a spiral or coil of insulated wire, through which a current of electricity from a battery is made to pass, it becomes a magnet as long as the current passes through the coil. When the current is stopped the iron ceases to be magnetic. Such a bar of iron, surrounded with a coil of wire for the purpose of magnetizing it, is called an **electromagnet** (Fig. 23). Electromagnets may be made much stronger than those produced by any other means. If a bar of hardened steel be thus magnetized, it remains a permanent magnet. The strength of an electromagnet is proportional to the strength of the current passing through the coil, and to the number of turns of wire in the coil. It takes time to produce a magnet by this means, some large magnets requiring from one to two seconds to reach their maximum strength.

The magnets of large dynamo machines frequently take as long as

ten minutes to rise to their full working strength. If into a coil of insulated wire connected with a means of showing minute currents of electricity a steel bar magnet be thrust, there is a momentary current sent through the wire by the inducing action of the magnet. On now suddenly withdrawing the magnet, a current is produced in the opposite direction in the wire. These facts will be referred to again when we come to speak of the action of the induction coil.
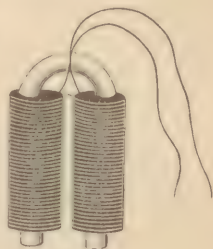
Theory of Magnetism.—The best explanation of the phenomena of magnetism is afforded by supposing that each molecule of the bar is a separate magnet; for, if the magnetized bar be broken into small pieces, each piece is found to be a perfect magnet. If this process of mechanical division be continued far enough we

FIG. 23.

will ultimately arrive at the molecule. Each molecule will then have two poles, one seeking the north and the other seeking the south end of the bar; or, when a bar of iron or steel is magnetized, the molecules are all so arranged that the same poles point in one direction, as rep-

FIG. 24.

resented in figure 24. By this theory we conclude that, when a piece of iron or steel is neutral, the molecules arrange themselves so that they satisfy each other's polarity, forming closed magnetic circuits among themselves, thus:
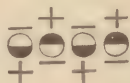
In molecules of chemical compounds the one kind of atoms is inherently electropositive, or north-seeking, and the other electronegative, or south-seeking. Chemical affinity is the manifestation of this polar energy acting between two kinds of differently polarized atoms or groups of atoms.

Electricity Produced by Chemical Action.—If in a vessel of water containing a little sulphuric or hydrochloric acid (1 : 20)

a strip of zinc and one of copper or platinum be immersed, and pre-
vented from coming in contact, no action is seen to take place, pro-
vided the acid and zinc be pure. If, however, we connect the two
strips of metal by a wire, or if the upper ends of the strips are brought
in contact, chemical action immediately takes place, and the follow-
ing phenomena are observed: (1) Small bubbles of gas are seen to
collect on the surface of the platinum strip, while the zinc slowly dis-
solves, and at the same time the acid begins to disappear.   In the
case of hydrochloric acid, the chlorine combines with the zinc,
and the hydrogen escapes from the opposite plate. (2) We find a
peculiar property manifested by the wire. If a magnetic needle be
placed near the wire, it is turned from its course. If the wire be
broken and the tongue be placed between the two ends, a tingling,
metallic taste is observed. If the plates are large, and the ends of
the wires are placed near together in a solution of copper sulphate,
the metallic copper begins to deposit on one of the wires. In a word,
a force is developed in the wires which we call **electricity.** If the
wires are separated from each other by air, the chemical action ceases,
the gas ceases to escape and the zinc to dissolve. The same phenom-
ena are observed when we substitute for the above metals zinc and
lead, zinc and gas retort carbon, etc. It is only necessary that the
plates be unequally acted upon by the fluid in which they are dipped ;

FIG. 25.

and the greater this difference, within certain
limits, the stronger is the force developed in the
wire. In order that these phenomena shall take
place the following conditions are necessary :

**The plates and connecting wires must
be conductors of electricity.**

**The liquid must contain some sub-
stance with which one of the plates can
form a chemical compound.**

Theory of the Galvanic Cell.—In order
to bring the working of the cell clearly before
the mind, let us assume the plates in figure 25 to
be platinum and zinc, and the exciting fluid to
be a solution of hydrochloric acid. There is
very positive evidence that in all electrolytic
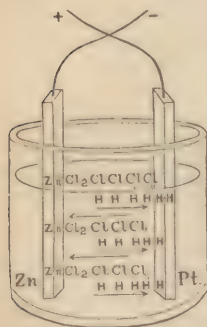fluids the substance in solution is split into its
component parts or ions. In the case of hydrochloric acid, when the
solution is dilute the most of the molecules are dissociated into free
chlorine and free hydrogen atoms. The chlorine atoms are charged
with negative electricity and the hydrogen atoms are charged with
positive electricity. If in such a fluid we put a strip of zinc,—itself a

conductor of electricity, and inherently charged with positive electricity,—it will attract the negatively charged chlorine atoms, and combine with some of them until it becomes charged with negative electricity, from the chlorine atoms, to a tension equal to that of the chlorine atoms, when this action will cease. If a strip of platinum be placed in the same solution no change will occur until the two plates are brought in contact, either directly or by means of a conductor. When such connection is made, the platinum plate, becoming charged with negative electricity from the zinc plate, attracts the positively charged hydrogen atoms. As soon as the hydrogen atoms discharge their charge of positive electricity,—which we may believe keeps them apart, as if they were a pair of pith-balls,—they combine into molecules at the platinum plate, and hydrogen gas is seen to accumulate upon this plate.

The zinc plate, having discharged its negative electricity, now attracts more chlorine atoms, receiving from them negative electricity, and again begins forming zinc chloride. There is thus a constant current of electrical force being conveyed from the one plate to the other as long as they are connected by a conductor, a constant escape of hydrogen from the platinum plate, and the formation of zinc chloride at the zinc plate.

By the above process the zinc plate is rendered negative,—or, as some prefer to say, its electrical tension is lowered below the normal by the withdrawal of positive electricity,—while the platinum plate is actually charged above the normal, and is in a positive electrical condition. It is this difference of electrical state which causes a neutralization through the wires as long as the exciting fluid and the zinc plate last, or as long as the chemical action continues. If the wires are disconnected the platinum plate soon becomes charged to a tension equal to that of the hydrogen atoms, and the zinc plate lowers its tension until the chlorine atoms will no longer be attracted to it or combine with it. The action then ceases until the connection is again made. The discharge is then continuous from the platinum to the zinc plate, and it can also be shown that a current passes through the liquid. Such is the best conception we possess of the simple galvanic cell which we have considered.

The Current or Circuit.—The circuit is said to be **closed** when the wires are connected and there is a constant flow or transfer of force through the wires and through the liquid. It is said to be **open** or **broken** when the wires are separated so that the transfer of force ceases.

If the wires from a galvanic cell or a collection of cells be connected with the earth instead of with each other, the current flows as

if the latter were really done ; and it makes no difference how far apart the wires connect with the earth. This is called **grounding** the battery. No current actually flows from one point to the other in the ground, but by bringing the plates in contact with the earth their electrical equilibrium is restored. This principle is made use of in telegraphy to avoid the necessity of a return wire. One of the wires of a battery situated at one of the stations is **grounded,** while the other passes to and through the other station and is then grounded at that point ; the current must pass between and through both stations to complete the circuit, or restore the equilibrium.

Electrical Tension or Electromotive Force.—When we speak of the normal electrical condition we have reference to the electrical state of the earth or bodies in contact with it. The earth is the great storehouse of electricity, as the ocean is of water. If water be taken up from the ocean and deposited upon the mountain side, it will run back to the sea in a stream, and can be made to do work, while reaching its former level, by turning a water-wheel. The water, in other words, has acquired power to do work by its change of position, which in mechanics is called **potential.** In the galvanic cell the equilibrium of electricity is disturbed, and it acquires power to do work in returning to its former state of electrical equilibrium. This property in electricity is called **tension, potential,** or **electro-motive force** (E. M. F.). The strength of the E. M. F. will, of course, depend upon the difference in the electrical condition of the two plates. It is our purpose to consider here only such practical points as we deem essential to the physician's knowledge in the use of galvanic batteries.

Electrical Units.—There are in common use among electricians certain units of measure, applied to currents, which it is convenient for the student to understand. The unit of **electromotive force** is called a **volt.** It is the power of the current to overcome resist-ance, and it is very nearly that of the Daniel or Calland gravity cell. The E. M. F. or the **voltage** of these cells is about 1.079 volts per cell.

The unit of resistance which a current encounters in its passage, and which must be overcome before an electrical circuit can be com-pleted, is called an **ohm.**

Just as there must be sufficient pressure of water to overcome the obstacles offered by friction and short curves in the pipes, before water will be delivered, so must there be sufficient voltage to overcome the high resistance offered by poor conductors, like the human body, before there will be a passage of current. The actual current, then, that produces effects, or does work, is produced by the excess of electric force over that which is required to overcome the resistance in

the conductor. In practice it is found necessary to employ a battery of from thirty to forty cells, according to the kind used, in order to secure electromotive force sufficient to overcome the resistance of the body and have a working excess of current.

The unit of measurement of the passing current is called the **ampere.** An ampere is the strength of current furnished by an electromotive force of one volt passing for any given time through a circuit whose total resistance is one ohm. It is the amount of work the current is able to do in a measured time.

But inasmuch as the tissues of the body could not endure a current of one ampere, the ampere is divided, for medical purposes, into 1000 parts, each of which is designated a **milliampere.** The unit of strength of current, then, in medical batteries is the milliampere, and represents not the actual quantity or dose, but is analogous to the strength of a solution which we might use externally and refer to as a five per cent. solution. As we speak of a pumping engine delivering a one-inch or a two-inch stream from a nozzle, the pressure remaining the same, so we speak of the current passing through a conductor as a one-milliampere or two-milliampere current.

Whenever it becomes necessary to measure the exact quantity or dose administered we make use of another electrical unit, called the **coulomb,** by which we mean the **unit of quantity.** The coulomb is such a quantity of electricity as would flow in one **second** through a circuit whose resistance is **one ohm,** under an electromotive force of **one volt,** or it is one **ampere-second.** The number of coulombs of quantity is determined by means of an instrument called the coulomb-meter, in which the current is made to decompose water into oxygen and hydrogen; the amount of this decomposition being proportional to the amount of current used. There is still another unit by means of which the total electrical energy is measured, and which is designated the **watt.** This represents the energy of a current flowing under a difference of potential of one volt and a strength of one ampere, and is sometimes called the **electrical horse-power.** It is expressible in mechanical units : 746 watts being equal to one horse-power, or one watt = $\frac{1}{746}$ horse-power. To estimate the electrical energy of any current, the E. M. F. in volts is multiplied by the number of amperes of current strength.

$$\frac{\text{Volts} \times \text{Amperes}}{746} = \text{horse-power.}$$

Legal Units.—The following units were adopted or confirmed by the International Electrical Congress at Chicago in 1893, and legalized by the United States Congress in 1894.

The **international ohm** is the resistance offered by a column of mercury, at $0°$ C., weighing 14.4521 gm. and having a length of 106.3 cm., and having a uniform cross-section throughout the length of the column.

The **international ampere** is such a current as will deposit from a neutral solution of silver nitrate 0.001118 gm. of silver per second, or 4.025 gm. per hour. The amperage of a current may be determined by depositing silver, and weighing the amount deposited in a given time.

The **international volt** is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere. It is represented by $\frac{1000}{1434}$ of the electromotive force of a standard Clark's cell, at a temperature of $15°$ C.

The **international coulomb** is the quantity of electricity transferred by a current of one international ampere in one second.

The **international farad** is the unit of capacity. It is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

The unit of work is the **joule**, which is equal to 10,000.000 units of work in the centimeter-gram-second system, and which is practically equivalent to the energy expended in one second by an international ampere in passing through an international ohm.

The unit of power is the **watt**, which is equal to 10,000,000 units of power in the centimeter-gram-second system, and which is practically equivalent to the work done at the rate of one joule per second.

The unit of induction is the **henry**, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second.

The Milliampere-meter.—This is an apparatus introduced into the circuit in order that the current strength the patient is receiving at any given time may be accurately measured. Its action depends upon the fact—discovered by Oersted, in 1841—that if a magnetic needle be mounted near a wire in which a current is passing it will be deflected. He found that if a current be sent along a conductor brought near to and parallel with a needle (see Fig. 27), it will cause a deflection of the needle in the direction shown by the curved arrows. He found, further, that the amount of this deflection will depend upon the strength of the current in the wire, and upon the proximity of this to the needle. If the conductor be returned upon the under side of the needle, so that the current shall flow in the oppo-

site direction, the needle will be still more deflected, and in the same direction. By using a number of turns of insulated wire,—*i. e.*, forming a coil, as shown in figure 26,—a multiplication of the deflecting power will be obtained. The plane of the coil must coincide with the plane of the earth's magnetic meridian. If this needle be suspended or mounted over a dial having a scale of degrees marked upon it, the number of degrees through which the needle swings under the influence of a certain current passing through the coil will indicate the strength of the current. In other words, such an instrument would be a **galvanometer** or **electrometer**.

If the scale is so divided as to read the current strength in amperes or milliamperes, the instrument would be known as an **amperemeter** or **milliampere-meter**.
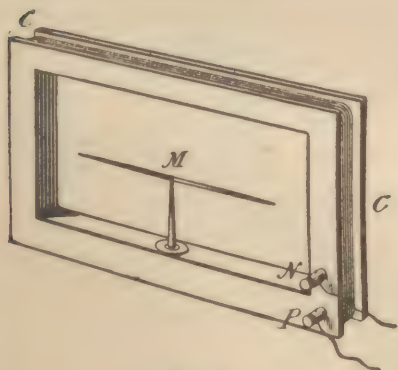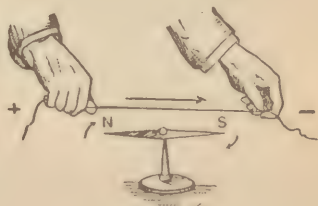
FIG. 26.   FIG. 27.

In the above-described milliampere-meter the instrument must be first adjusted with the magnet exactly in the magnetic meridian. The instrument must be carefully leveled before the reading is taken. The needle will then point to zero on the scale.

To avoid this adjustment, milliampere-meters are now often constructed with the needle mounted in the field of a permanent magnet, which serves to bring the magnet always to zero when no current is passing through the coils, regardless of the position of the instrument. Milliampere-meters are sometimes employed in which the elastic force of a coiled spring is applied to bring the needle quickly to rest, or cause it to "dead-beat," without any delay from oscillations. The strength of current to be applied to the human body varies greatly, according to the effect to be produced, from 10 to 300 milliamperes.

6

Forms of Cells.—We have thus far discussed only one form of cell. The term **battery**, strictly speaking, is applied to a collection of cells ; but it is frequently applied to a certain form of cell. Various kinds of cells are in common use.

One difficulty in the working of the simple cell we have already described is that the hydrogen accumulates on the platinum plate and prevents contact with the liquid, and thus obstructs the current. To obviate this, various means have been used to prevent this gas from accumulating on the platinum.

In **Grove's** cell (Fig. 28) the platinum plate is suspended in a porous earthenware cup filled with strong nitric acid and placed in

the center of a larger cup containing dilute sulphuric acid ($1 : 12$). The nitric acid oxidizes the hydrogen, converting it into water before it reaches the platinum.

Bunsen's cell is constructed in the same way as the above, except that the platinum is replaced by the cheaper gas retort carbon.

In the working of the above cells the nitrous fumes evolved are very objectionable. To avoid this, a solution of chromic acid in sulphuric acid—made by adding to eighteen parts of water four parts of potassium bichromate and four of sulphuric acid—may be used. The chromic acid serves to destroy the hydrogen in the same way as the nitric acid, and no porous cup is needed. The elements used are zinc and carbon. This cell gives a strong current for a short time, and is one of the best in use for medical purposes. The zinc plates are always removed from the liquid when the battery is not in use. In some medical batteries a solution of acid sulphate of mercury in water is used as the exciting fluid instead of the above. In this case the plates are small, and made of zinc and carbon. The zinc combines with the sulphuric acid, and mercury instead of hydrogen is set free. Another form of battery is one in which the exciting fluid is diluted sulphuric acid and the elements zinc and silver. The latter are inclosed in a layer of chloride of silver, which is intended to prevent the hydrogen from accumulating on the silver plate by combining it with chlorine. $2AgCl + H_2 = Ag_2 + 2HCl$. These cells are usually made in the form of long, narrow

FIG. 28.

cylinders, so as to occupy a small space, and are very constant and effective.

In the **Leclanché** cell (Fig. 29), as usually constructed, the elements are a plate of carbon and a rod of zinc. The carbon plate is surrounded by a layer of peroxide of manganese, or ferric oxide, to serve as a depolarizing agent. The exciting fluid is a strong solution of ammonium chloride in water. This cell is in very common use where an open circuit is used, is very constant, requires attention only at long intervals, and is inexpensive. Various modifications of this cell have been proposed, and of these the Law cell has the advantage of being most durable.

FIG. 29.
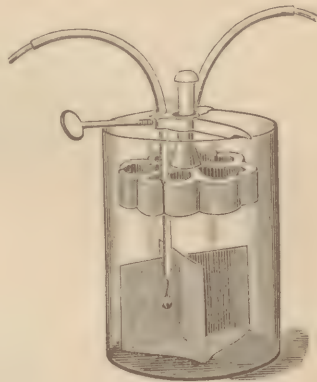
FIG. 30.

The **Callaud** cell (Fig. 30) is constructed as follows: The elements are zinc and copper. The former is suspended in the upper portion of a solution of copper sulphate contained in a glass jar. The copper plate lies at the bottom of the jar, and the wire attached to it is covered with gutta-percha, for the purpose of insulating it. From time to time copper sulphate crystals are dropped into the jar, to keep up the supply.

This cell is good when used on a closed circuit and the battery is in constant use. It is very constant when kept in good order, but has a low electromotive force, and is seldom used in the construction of medical batteries.

Care of Batteries.—In order that a battery may perform its work it will need some care in its management. All metallic connections, as well as the wires through which the current is to pass, must be of good conducting material. Copper or silver wire is usually

employed for conductors, and where two wires are meant to connect their surfaces must be bright and free from oxides, which are poor conductors. As far as possible, a uniform strength of exciting fluid should be maintained. In most batteries this will require entire renewal from time to time, in order to supply new material for chemical action and to remove the products of former action.

Local Currents.—Owing to the imperfections in the zinc used in the construction of batteries, it is unequally acted upon by the liquid. The points where the zinc is harder, or contains iron, lead, or arsenic, act as negative plates to the rest of the zinc, and thus currents are set up between them which eat away the zinc and cause a serious loss of material, as well as of force. When the battery is not in use bubbles of hydrogen gas will be seen to escape from the zinc plate, which slowly dissolves. When in use, this hydrogen prevents contact between the plate and the liquid, thus greatly weakening the action upon the plate and increasing the resistance to the passage of the current from the liquid to the metal. "Amalgamation" of the zinc prevents this action by forming over the surface of the plate a homogeneous layer of zinc amalgam.

To amalgamate the zincs, first wash them in dilute sulphuric acid (1 : 6), and then, while still wet, pour mercury upon them, and rub in the drops until the whole surface is uniformly bright and smooth. Or, they may be dipped in a saturated solution of bichloride of mercury (corrosive sublimate) containing a few drops of hydrochloric acid. It is well to keep a little mercury in the bottom of each cell, which keeps the plate amalgamated. A hissing sound, or the evolution of hydrogen from the surface of the zinc, is a sure sign that the zincs need re-amalgamating.
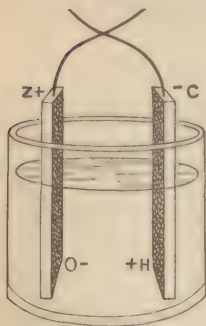
FIG. 31.

Polarity of the Elements of Batteries.— A serious hindrance to the working of batteries is what is called the **polarization of the plates.** We have already referred, when speaking of the construction of cells, to the accumulation of hydrogen on the carbon or platinum plate. When the current is of considerable strength, oxygen accumulates on the zinc plate and hydrogen on the opposite one. We then have a layer or plate of hydrogen against the carbon and a layer or plate of oxygen against the zinc. The former of these is positive and the latter negative, and they are connected by the same wires as the primary plates, as will be seen by a glance at figure 31. Not only is the liquid kept from perfect contact

with the plates, but, owing to the action of the liquid upon these new gaseous plates, a current is developed in the opposite direction to that of the primary current, and which may become so strong that it almost entirely overcomes the original current and destroys the efficiency of the battery.

Some method must be adopted, therefore, to prevent the hydrogen from accumulating upon the carbon or platinum plate. Nitric or chromic acids, oxides of manganese, copper or iron, silver chloride, and copper sulphate are all used for this purpose.

Secondary or Storage Batteries.—The polarity of the plates of a battery cell is utilized in the **secondary** or **storage batteries.** The cell contains two or more plates of large size, constructed of sheet-lead ; or one is made of sheet-lead, to be connected with the negative pole, and the other of peroxide of lead, to be charged from the positive pole of the charging battery or current. The E. M. F. of such cells is about two volts during discharge. The cell is filled with dilute sulphuric acid. The plates are polarized by passing a current through the battery. The hydrogen accumulates in or upon one plate and the oxygen in the other. On now disconnecting the charging battery, it is found that a current may be obtained from the polarized cell for some time, but in the direction opposed to that of the charging current. When the plates of this battery are once charged they will remain charged for some weeks, and the current may be obtained at any time by connecting the wires from the opposite plates.

Resistance of Conductors.—Conductors are bodies which allow a ready transmission of the electrical impulse through them, and are contrasted with another class of bodies, called non-conductors or insulators. These terms, however, are only relative.

Some bodies conduct electricity with great ease, while others offer more resistance to the passage of the current or entirely refuse to allow an appreciable amount to pass. Even the best conductors offer some resistance to the passage of the current. The metals are the best conductors, and of these silver is the best conductor known. Copper is second only to silver, and when both metals are pure the difference is but slight.

If we compare wires of the same material, but of different sizes and lengths, we find that **the resistance of wires increases with the length and diminishes as the area of the cross-section increases.** When a cell is in action the current not only meets with resistance in the wires, but also in the liquid of the cell through which it has to pass. This last resistance is usually much greater than that of the wires, and is an important element in determining the strength of the current.

Ohm's Law.— This law states that the strength of a current developed by a battery is equal to the electromotive force divided by the resistance. By electromotive force we mean the force with which the electric current is set in motion, or the difference in potential of the two plates of the cell used. This law may be stated algebraically as follows: $C = \frac{E}{R + r}$, where R represents the internal resistance of the liquid, r the external resistance, or that offered by the wire, and E the electromotive force, which is always the same when the same metals and exciting liquids are used. In any given form of battery, variations in the strength of the current must be due to variations in resistance, either in the external or the internal part of the circuit, to a change in the strength of the exciting liquid, to polarity of the plates, or to secondary currents. We have already spoken of the resistance offered to the current by the polarity current, flowing in the opposite direction, and which sometimes becomes almost as great as the electromotive force can overcome. It is clear that in order to increase the value of C, in the above formula, we must increase E or diminish R and r. To increase the electromotive force we select such metals and liquids as will give us a relatively high intensity of current. We may increase the intensity of the E. M. F. by joining several cells, so that the force of the one may be reinforced by the next, and so on. This is done by connecting the zinc of the first to the carbon of the second, the zinc of the second to the carbon of the third, etc. Each cell added to the series adds to the current its E. M. F., diminished by its internal resistance, the external resistance being too small to be regarded. The formula applied to the series would be, when n equals the number of cells: $C = \frac{n E}{n R + r}$. Now, when the external resistance in the wire, r, is very small in comparison with R, as when flowing through an ordinary copper wire, it may be disregarded, and the equation then becomes $C = \frac{E}{R}$. That is, the effect of a battery of several elements, in such a case, is no greater than that of a single cell. If, however, the external resistance, r, is great, as when the electrodes are applied to a human body, which has a resistance many times greater than the usual value of R, the value of C increases or diminishes very nearly in the same ratio as the number of cells. For medical purposes, therefore, we usually combine the cells as above described. Elements or cells so arranged are said to be arranged **in series**, or arranged **for intensity.**

We may also increase the value of C, in the above formula, by increasing the size of the plates, provided the external resistance is small. By so doing we do not increase the electromotive force of

the current in the wire, but we reduce the resistance in the cell, by virtually combining several plates into one, and increasing the surface exposed to the liquid, without increasing the distance through which the current has to pass in the liquid. Whether the plates in this case are all in one or different cups, the current only has to traverse the fluid from one plate to another. The internal resistance in this arrangement is small. Where a small resistance is to be overcome, therefore, large plates are to be preferred ; or, which is the same thing, all the zinc plates of the battery may be connected, and all the carbon plates. When the cells are arranged in this manner they are said to be arranged in **multiple arc,** or **for quantity.** The **poles** or **electrodes** of a battery of cells are the conducting wires ; that attached to the zinc plate is the **cathode** or **negative** electrode, and
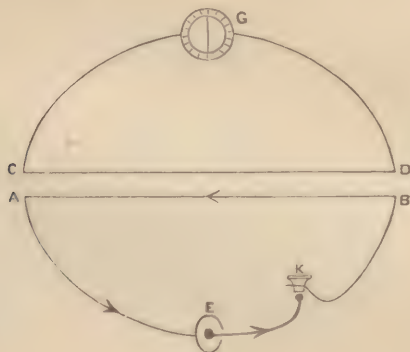
FIG. 32.

that attached to the platinum, carbon, or copper plate is the **anode** or **positive** electrode.

In electrotherapy the term **electrode** is often used to designate the appliance fastened to the end of the wires for application to the patient, while the wires are called **rheophores.**

Induced Currents.—If a current of electricity from a battery be passed through one of two parallel wires, B A and C D (Fig. 32), lying near together, no current is observed in C D as long as the current in B A is constant ; but if this be abruptly stopped, an instantaneous current is developed in C D, which we can demonstrate by connecting this wire with a galvanometer, G. When we make the current pass from B to A, the current in the wire C D takes the direction from C to D ; but on breaking the primary current, the induced current

takes the direction D to C. If, therefore, we rapidly make and
break the primary or battery current by means of the key, K, we
shall have a rapid to-and-fro current in the secondary wire, C D.
Now, if these wires be covered with silk, or insulated, and are wound
together around a spool or bobbin, the conditions of the experiment
will remain unchanged, and we shall have the same phenomena in the
coiled wires as in the straight. Such a coil is known as an induction
or Rhumkorff coil. The strength of the current in the secondary
wire, or the induced current, will vary directly as the length of the
wire acted upon, the strength of the battery or primary current, and
inversely as the distance the wires are from each other.

The Induction Coil.—It is customary, in constructing an induc-
tion coil, to make the primary coil of large, thick wire, so as to
allow the battery current to pass with as little resistance as possible,
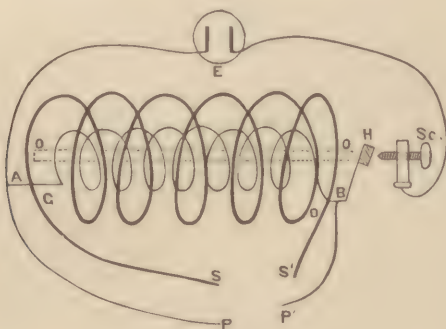
FIG. 33.

and to make the secondary coil of a much longer and thinner wire.
The former is made into a smaller coil, which slips into the latter,
but the two are separate and distinct. Into the inner coil is pushed
a bundle of soft iron wires, which act as magnets when the battery
current is sent through the coil. A small armature, or piece of soft
iron fastened to a spring, vibrates before the end of the bundle of
wires. When no current is passing the spring rests against the point
of the screw, Sc., figure 33. When a current is sent through the inner
coil from B to A, an induced current is produced in the outer coil,
from S to S' or from C to D. At the same instant the current B A
magnetizes the core of wires O O, and the hammer H is drawn toward
it and away from the point of the screw. This breaks the current
at that point, the core demagnetizes, the spring brings the hammer

back to the screw, and the process is repeated as long as the current from the battery E lasts. The induced current in S S' is, therefore, a **to-and-fro** current, or a **make** induced in one direction, and a **break** induced in the opposite direction.

This current is known as the **secondary, induced, interrupted,** or **faradic current.** The two wires from the battery cell (Fig. 34) are connected with the primary coil by the binding posts, and carry the battery current. The other wires shown are the terminal wires of the outer or secondary coil, and carry the induced current.

Extra Current.—It is very evident that each turn of wire in the primary coil lies very close to and parallel with the adjoining turns of the same wire, and that these consecutive turns may be considered as constituting a series of parallel wires. In fact, every variation of the current in the wire A B, figure 33, generates electromotive force
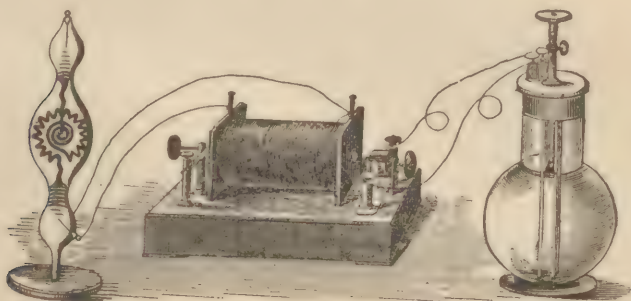
FIG. 34.

in the contiguous turns. An induced current is thus produced in the wire A B, which obeys the same laws as that induced in the independent wire C D, and in the direction opposed to the battery current when the latter is made or increased, and in the same direction when it is broken. This current is known as the **primary induced** or **extra current.** During the making or increasing of the battery current this **extra current,** acting against the battery current, retards or resists it, and hence is not felt at the poles P and P'. At the **break** this current goes in the opposite direction, and, as there is nothing to resist it, may be felt with its full force at P and P'. This current is therefore **interrupted,** and is felt only at the break of the battery current, and always in the direction of this current. The primary induced or extra current is feebler than the secondary, because the length of wire acted upon is shorter. As we have just

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said, the **make** extra current retards the battery current, so that it takes an appreciable time for this current to attain its maximum force ; and the **make** induced current is weakened in proportion to the longer time required. The secondary current developed at the time of making the battery current is therefore weak, and its physiological and chemical effects are almost inappreciable. The **break**—secondary as well as primary—is developed with its full electromotive force instantaneously ; hence, it alone has an appreciable effect when a resistance such as the human body is put into the circuit.

Influence of the Core.—As we have stated above, when a galvanic current is sent through a coil of wire wound about a bar of soft iron, the bar becomes a magnet as long as the current passes, and loses its magnetism as soon as the current in the wire is broken. The effect of the bundle of soft iron wires is the same as that of a single bar. Moreover, when a magnet is suddenly made or destroyed, it causes a current to flow through the wire wound about it. The effect of the magnetic core is, then, only to retard the battery current when it is first passed through the coil, and to still further weaken the induced currents developed by it. Its sudden demagnetization reinforces the break currents and makes them stronger. The currents are further modified by means of a draw tube made to inclose more or less of the primary coil. When this is completely withdrawn the current is strongest, and when the inner coil is completely inclosed by it the currents are considerably weakened. Occasionally the secondary coil is made to include any desired length of the primary, and thus the current may be varied at will. Figure 34 shows an induction coil with Grenet cell ready for use.

Magneto-electricity.—Besides chemical action, other methods of producing electricity may be employed. We have above referred to the effect of suddenly making and destroying a magnet within a coil of wire. The same effect is produced when the magnet is made to approach or recede from the coil of wire or when the magnet is increased and decreased in strength. The simplest magneto-electric apparatus is composed of a strong horseshoe magnet, before the poles of which two short, soft iron bars, called armatures, mounted on a shaft and wound with coils of wire, are made to revolve by a crank. As the soft iron approaches the poles it becomes a magnet, and induces a current in the wire. As it recedes from the poles the current in the wire is reversed, but by a pole changer it is made to pass from the instrument in the same direction.*

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* In another form of the machine the coil of wire is on the magnet, and the current is produced by the variations in the magnet itself, caused by the varying distance of the armatures.

By multiplying the number of magnets and armatures, by using the current developed to strengthen the magnets, and by revolving the armatures at a high rate of speed, a very large amount of electricity may be produced. The electric light is now very generally supplied with electricity by machines made upon this principle and driven by steam or water-power. Such machines are called dynamo-electric machines. Small machines are sometimes employed for medical purposes, which have been improved by M. Gaiffe so as to give much better results than the older forms of this apparatus. In these machines the electricity is the result of the conversion of mechanical force into electrical force, the two being mutually convertible.

Thermo-electric Currents.—If two bars of dissimilar metals be soldered together at one end, thus: $\overset{a\ b}{\underset{c}{\diagdown}}$, and the junction c be heated while the ends a and b are cool, electricity will pass between a and b when connected by a wire. The direction of the current will depend upon the metals composing the couple. If the metals be bismuth and silver, the current will be from the former to the latter; if German silver and iron, the current will be from the former to the latter. By arranging a large number of such pairs thus, –WWWW , so that alternate junctions can be heated, a current of considerable strength may be produced. Such a series is called a *thermo-electric pile*, and may be constructed by arranging the bars in the form of rays around a hollow center, in which a lamp or fire can be kept burning, and thus furnish a constant current of electricity. Thermo-electrical currents have not been used in therapy.

Physiological Effects of Electricity.—Electrical currents exert a marked physiological effect upon the nerves, the muscles, and the circulation of the human body when it is made a part of the circuit. A constant or galvanic current has a refreshing effect upon a nerve, as well as upon a muscle, through which it is passed. A muscle is able to perform more work under its influence than without it. Under its influence the circulation of the blood in any part of the body may be increased, which increase lasts for some time after the electrodes have been withdrawn. The physiological effect of the negative pole seems to be greater than that of the positive. The interrupted, induced, or faradic current stimulates nerves most when passed in the direction of the natural nerve current; this seems to be its principal physiological effect. The stimulation seems to be more marked when the interruptions of the current are very rapid and it is induced in a long wire of small size. For this reason the recent coils are made with a means of getting extremely rapid interruptions. Drugs may be carried through the skin by the galvanic current. This process is

known as *cataphoresis*. The remedy, in solution, is placed between one of the electrodes and the skin, and is carried through the skin into the tissues by the passage of the current.

For more extended remarks upon this part of the subject the student is referred to one or more of the many manuals * upon the subject.

Chemical Effects of Electrical Currents.—When a strong galvanic current is passed through a vessel of water containing a little sulphuric acid, the liquid is decomposed, hydrogen gas is given off at the negative pole, and oxygen at the positive. This process is called **electrolysis.** If we perform the same experiment with a solution of a salt of one of the metals, the metal appears at the negative pole and the negative element or radicle appears at the positive pole. If the same current be passed through an animal tissue, the following changes take place : The water in the tissue is decomposed, the hydrogen appears at the negative pole, along with the hydroxides of potassium and sodium, while the oxygen, with the non-metals or acid radicals, appears at the positive. The nascent oxygen and acids surrounding the positive pole attack the neighboring tissues and convert them into a hard eschar, while the alkalies at the other pole exercise their caustic properties and form a soft, frothy mass, containing hydrogen gas in small bubbles.

When a sufficiently strong and somewhat prolonged current is applied to the skin, a similar effect to the above is produced at the point of contact of the electrodes. At the positive electrode the skin first becomes red, with a burning sensation ; then an eschar is produced, with an acid reaction of the tissues. The eschar resembles that produced by a strong acid. At the negative electrode there is a vesicle formed containing an alkaline liquid ; if the action be prolonged, more extensive ulceration takes place. From this it will be seen that strong currents should be used with care, unless it be desired to produce destruction of tissue, as in the removal of tumors, superfluous hairs, etc. When destruction of tissue in a deep-seated organ has been produced by electricity, the eschar is absorbed without suppuration, provided the destruction is not too extensive. By the use of a suitable current regulator, the current used for incandescent lights may be employed for medical purposes, instead of that from a galvanic battery. The effects of the magneto-electric current are very similar to, if not identical with, those of the galvanic current. Recently the use of frictional electricity in the treatment of disease has been revived, and advised as a substitute for faradic electricity.

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* De Watteville, Massey, Bartholow, or Beard and Rockwell.

The effects of this form of electricity have not been so well studied as those of the faradic and galvanic, but clinical results seem to indicate that it is even more stimulating than the latter.

Chemical Effects of the Galvanic Current Outside of the Animal Body.—We have seen that when a current of electricity from a battery or a magneto-electric machine is passed through a solution of the salts of the metals, they are decomposed, the metal appearing at the negative pole and the negative radicle at the positive pole.

The salts of some of the metals—the earths and the alkalies—require a very strong current, while some of the other metals do not require more than the current of one or two ordinary Leclanché cups. If the current used be not too strong, the metal is deposited upon the negative electrode in a compact, tenacious form, adheres very firmly to the surface, and is capable of taking a polish. For this reason the process of depositing metals upon the surface of other metals has come into extensive use in the arts of electroplating and electrotyping. The principal metals used to deposit upon others in this way are gold, silver, copper, and nickel. The objects to be attained are to protect easily oxidizable metals from rust, to preserve a brilliant surface, and to coat cheaper metals with the more valuable ones. This process is known as **electroplating.**

Electrometallurgy or Electroplating.—Silver and copper are more easily deposited than most other metals. The strength of current needed to deposit these metals is rather feeble, unless the surface to be coated is large. The quantity of electricity should be varied according to the surface to be coated, larger surfaces requiring a stronger current than smaller ones. The strength of the solution of the metal to be deposited must be governed somewhat by the material composing the article to be plated and the strength of the current, and will have to be determined experimentally by the beginner. When the proper strengths of solution, current, etc., have been found, these should be kept as nearly constant as possible. The plating solution may be kept of constant strength by suspending from the positive pole of the battery a plate of the same metal as that contained in the solution, the size of which should be nearly equal to that of the article to be plated.

SOLUTION, DIFFUSION, AND DIALYSIS.

Solution.—The power of water to dissolve substances is one of the most familiar of its properties. All liquids possess the same power to a greater or less extent; but liquids vary greatly in their solvent power, which is usually limited to a certain class of bodies. Thus, mercury will dissolve a number of the metals, alcohol is the proper solvent for the resins, ether for the fats and some gums, and water for the ordinary metallic salts. Water is by far the most universal solvent, and for this reason it is commonly used as the medium of chemical changes.

The solvent power of water varies greatly with different solids. While some bodies absorb water from the air and become liquefied, or **deliquesce**, others require several hundred times their weight of water to dissolve them, and some will not dissolve in it at all. As a general rule, the solvent power of water for solids increases with the temperature; but there are a few exceptions to this rule.

By the solubility of a substance is meant the amount of the substance which will be taken up by the solvent. The solubility of a substance is absolutely definite at a given temperature, and the amount which 100 parts of water will take up has been determined for nearly every known substance.

A knowledge of the solubility of ordinary solids is very important to the medical student as well as to the chemist. The law of compatibles is really the law of solubilities. A table will be found in the Appendix giving the approximate solubility of those salts most commonly met with, and to which the student should refer for information concerning the solubility of substances. When a liquid has dissolved all of a solid that it can take up, it is said to be **saturated** for that temperature; but saturation of a liquid with one solid does not prevent it from dissolving others, and in some cases the solvent power of the liquid is thereby increased. When two or more salts are dissolved in a liquid an exchange of the metals and acids may take place, according to the laws of Berthollet (p. 107), modified by the strength of the affinities of the radicles present and the relative quantity of each present.

Solution of Gases.—Most liquids dissolve gases as well as solids. The quantity of gas which one c.c. of any liquid will dissolve, when the pressure of the gas upon it is 760 mm., is called its coefficient of absorption. As in solids, this coefficient must be determined by experiment for each gas; this generally decreases as the temperature increases, although each gas obeys a rule of its own, which can be

SOLUTION, DIFFUSION, AND DIALYSIS. determined only by experiment. The **volume** of gas absorbed by a liquid at any given temperature is the same, whatever the pressure. The **quantity** of gas dissolved, therefore, increases and decreases with the pressure. When a liquid is exposed to a mixture of gases, it dissolves each in the same proportion as if it alone were present and exerting its own share of the total pressure. Thus, when the air— a mixture of oxygen and nitrogen in the proportion of 1 to 4 respectively—is exposed to a mass of water, we find that the gases are absorbed by the water in the proportion of 1 to 1.87 respectively.

Nature of Solution.—The term solution, as commonly used, embraces two entirely different processes—the one mechanical or **physical,** and the other **chemical.** In physical solution the identity of the solid is preserved, as well as that of the water; and by evaporation of the water we may obtain it again unchanged. In some cases there seems to be no manifestation of chemical action between the water and the solid. In other cases, which seem at first sight to be equally simple, there is heat developed or heat absorbed, which, with the fact that certain solutions have a constant boiling point when a definite amount of solid or gas is present, leads us to suppose that in these cases there is a true but feeble chemical union of the salt with the solvent. When the solid separates again in crystals, it takes a part or all of the water with it as water of crystallization. It is now generally believed that in dilute solutions of certain substances called electrolytes, *i. e.*, those substances which conduct electricity and are capable of being separated by this current into their component parts or ions, these ions exist separately in the solution. That is, when the metallic salts, the inorganic acids, or bases are dissolved in water they dissociate, and exist in that condition. According to this idea, in a weak solution of common salt we have free sodium and free chlorine atoms, and but few NaCl molecules. When the solution is concentrated by evaporation, a recombination of the atoms takes place and the salt molecules are reformed. For the experimental data upon which this notion rests the student is referred to one of the larger handbooks on chemistry. A **saturated solution** is regarded as a definite compound of the liquid and the substance dissolved. The metallic alloys are in some cases mere mixtures, and in others they seem to be veritable compounds. When a metal dissolves in a dilute acid there is, at first, a chemical action between the acid and metal, by which a soluble compound is formed. This then dissolves in the water present, as above described. This double process is sometimes termed **chemical solution.**

Diffusion of Liquids.—When one liquid dissolves in another the process is called **liquid diffusion.** If upon the bottom of a vessel

containing pure water we pour some water colored with a little anil-
ine red, by delivering it through a funnel tube so as to prevent the
mingling of the two, and then allow the vessel to remain at rest for
some hours, the color will be found to have diffused itself throughout
the water.

If instead of a colored water we use a strong solution of common
salt, having a high specific gravity, we shall find by appropriate tests
that the salt has passed throughout the entire liquid. The rate of
diffusion in these cases increases, for all substances, with the tempera-
ture. This is because the rapidity of motion of the molecules—to
which we ascribe the phenomena of heat—increases with the tempera-
ture.

Dialysis.—If, in the experiment just mentioned, we should inter-
pose a porous partition of earthenware or parchment between the salt
solution and the pure water, the result would be the same—the salt
would pass through the partition into the water. If, however, we
use on one side of the partition a colloidal substance like gelatin or
albumin, we shall find that very little of these pass through it into the
water. Crystallizable bodies pass through the membranes with ease,
while those which do not crystallize—called colloids—pass with great
difficulty. This property of bodies is made use of to separate the one
class from the other. The process of the diffusion of liquids through
porous membranes is called **osmosis.** Certain porous walls have the
power of allowing some molecules to pass through them, while
other molecules are not allowed to pass. Thus, if a porous earthen-
ware cup, such as that used in the Bunsen or Grove cell (see Fig.
28), be soaked in a solution of copper sulphate, then in a solution
of potassium ferrocyanide, there is formed in the pores of the cup a

continuous layer of copper ferrocyanide. Water
can be filtered through this cup ; but if we attempt
to filter a sugar solution through it, only the water
molecules will pass. The **dialyzer** is an apparatus
consisting of a shallow vessel, provided with a bot-
tom of parchment or some porous membrane, in
which the solution to be dialyzed is placed, and the
vessel is then floated upon pure water in a larger
vessel. (See Fig. 35.) The volume of the water
should be eight or ten times that of the solution to
be dialyzed. In the course of two or three days
the crystallizable bodies in the solution will be found in the water of
the outer vessel, and the colloid bodies will be in the dialyzer.

Dialysis is employed to prepare a pure colloid material by dialyzing
from it all crystallizable salts. A complex mixture, like the contents

of a stomach, is submitted to dialysis for the purpose of separating from it the crystalloids which it may contain, so as to get them in a pure watery solution for analysis.

CRYSTALLOGRAPHY.

Formation of Crystals.—When substances change from the melted to the solid state or separate from a solution, many of them assume a regular geometrical form, called a crystal. The process is called **crystallization.** The same substance always assumes the same crystalline form under the same conditions. Under different circumstances, as high and low temperatures, the same substance may have two different crystalline forms, in which case it is said to be **dimorphous.** Different salts of the same metal assume different forms, unless the structure of the molecules is very similar. Thus NaCl, KCl, NaBr, KBr, and KI crystallize alike, in cubes, while K_2SO_4, KNO_3, and KCl assume different forms. The form of the crystal is, therefore, to a certain extent, an index of the molecular structure of the body. There are some substances, like gelatin, albumin, fibrin, etc., which can not be made to assume the crystalline form. Such bodies are called **colloids,** while those which crystallize readily are called **crystalloids.** In order that crystals may form, it is necessary that the molecules shall be free to move—*i. e.*, cohesion must be overcome to such an extent that it shall not prevent the free movements of the molecules. This condition prevails in solutions, in the melted state, or in the gaseous state. When we evaporate off the solvent, in the case of solutions, we may obtain the crystals with ease. The more slowly the evaporation takes place, the larger and more perfect are the crystals obtained. As a rule, bodies dissolve more readily and in larger quantities in hot than in cold water. A hot saturated solution of any crystallizable salt deposits the excess, on cooling, in the form of crystals. A liquid which is depositing crystals will do so more readily when foreign bodies—as sticks, strings, etc. —are suspended in it. Milk-sugar is usually crystallized in this way, upon strips of wood. Advantage is taken of this fact to prepare parlor ornaments in the shape of grass, leaves, etc., covered with alum crystals, which may be colored with aniline colors by previously coloring the solution.

When bodies are sublimed they usually assume the form of crystals in coming back to the solid form ; for example, iodine and sulphur. When we evaporate down a solution containing two or more salts of different degrees of solubility, the least soluble crystallizes first, and may thus be separated from the more easily soluble ones.

This fact is taken advantage of in preparing common salt from sea-water or salt springs. The common salt, being less soluble than the magnesium and potassium chlorides, bromides, or iodides, with which it is often associated, separates first, and may be skimmed off, leaving the others in the **mother-liquor**—the name given to the liquid from which crystals are obtained.

When a substance crystallizes from a solution, the crystals, if perfect, are nearly free from impurities. We therefore take advantage of this method to purify substances.

Water of Crystallization.—Most substances, when they separate from a solution, take with them a certain definite amount of water as a necessary part of the crystal. This water is known as **water of crystallization.** The crystals of a given substance, when deposited at the same temperature, always contain the same amount of water. Thus, the crystals of copper sulphate contain five molecules of water for one of the salt, and the formula of the crystal is written thus:

$$CuSO_4.5H_2O \text{ or } CuSO_4.5Aq.$$
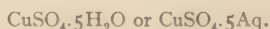
Ferrous sulphate crystals have the formula, $FeSO_4.7H_2O$.
Sodium carbonate   "   "   " $Na_2CO_3.10H_2O$.
Alum   "   "   " $K_2Al_2(SO_4)_4.24H_2O$.

A few salts have different amounts of water of crystallization when separated at different temperatures. Thus, crystals of manganous sulphate have the formula:

$MnSO_4.7H_2O$ when crystallized below 6° C. (42.8° F.).
$MnSO_4.5H_2O$ "   "   between 7° and 20° C. (44° and 68° F.).
$MnSO_4.4H_2O$ "   "   "   20° and 30° C. (68° and 86° F.).

The crystalline forms in these three cases are entirely different, showing that the molecules of water are necessary to the form of the crystal. The water in these cases is held by a feeble force, and may generally be driven off by exposing the crystal to a temperature of 100° C. (212° F.) in a dry atmosphere, when the crystals fall to powder.* In some cases the crystals lose their water at ordinary temperatures and crumble to a powder. They are then said to **effloresce.** On the other hand, some dry substances, when exposed to the air, absorb water. They are then said to **deliquesce;** such a body is said to be **deliquescent** or **hygroscopic.**

Silver nitrate ($AgNO_3$) and a few other salts crystallize without water of crystallization.

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* It frequently happens that one molecule of the water of crystallization requires a much higher temperature to expel it than the rest. Thus, in $CuSO_4.5H_2O$, four molecules are driven off at 100° C., while the fifth requires a temperature of 200° C. To distinguish the water that is more firmly held, it is called *water of constitution*.

Forms of Crystals.—A great variety of crystalline forms are met with, but for convenience of study all may be classed in six systems. These systems are based upon the number, length, and inclination of certain imaginary lines, called axes, passing through the center of the crystals and connecting opposite parallel sides or opposite angles. (See Fig. 36.)

The following figures represent a few of the most common and simpler forms of crystals met with, and the most of those spoken of in the following pages:
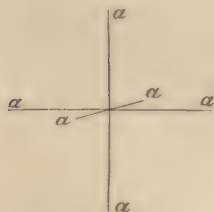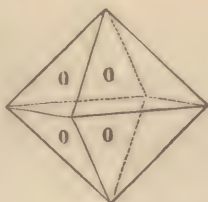

FIG. 36.

FIG. 37.—REGULAR OCTAHEDRON.
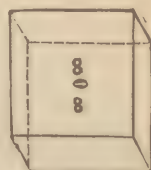
FIG. 38.—CUBE.

FIG. 39.—PRISM.
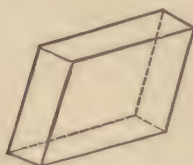
FIG. 40.—OBLIQUE RHOMBIC PRISM.
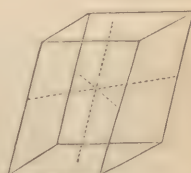
FIG. 41.—RHOMBOIDAL PRISM.

FIG. 42.—HEXAGONAL PRISM. Modified by pyramid.
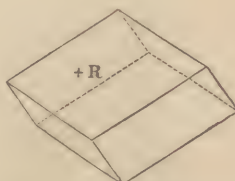
FIG. 43.—RHOMBOHEDRON

PART II.

THEORETICAL CHEMISTRY.

Molecules.—A molecule has been defined as a collection of atoms held together by chemism or affinity in such a way as to neutralize their tendency to combine with outside atoms.

When the atoms comprising a molecule are of the same kind, it is said to be **elemental** or **simple**; when of different kinds, it is called **a compound molecule.**

When, by chemical means, we cause a rearrangement of the atoms of compound molecules, we may obtain two or more kinds of elemental molecules; but with elemental molecules we only obtain one kind. We may illustrate this by the following formulæ:

Let **ab** and **ab** represent two compound molecules. By a rearrangement we may have **aa** and **bb**. If we take **aa** and **aa** we shall not be able to obtain anything else but **aa** and **aa**.

If in the molecules represented by HOH and HOH we cause the rearrangement by a strong electric current, we shall have **HH, HH,** and **OO,** or two kinds of molecules entirely different from the original molecules and from each other.

If, on the other hand, a current of electricity be caused to pass through either HH + HH or OO + OO, we will only obtain HH and HH or OO and OO. By this and other methods known to chemists, about seventy-four elemental molecules or different kinds of atoms have been discovered. By a **chemical element,** then, we mean a substance that has never been found to contain more than one kind of matter; and a compound body is one that has been shown to contain more than one kind of matter or atoms. These seventy-four different molecules or atoms have each received a separate name, the name of the molecule and that of the corresponding element being the same. These names are given in the first column of the following table:

THE CHEMICAL ELEMENTS.

NAME.	SYMBOL.	EQUIVALENCE.	SPECIFIC GRAVITY.	‡ ATOMIC WEIGHT. O = 16	‡ ATOMIC WEIGHT. H = 1	ELECTRICAL STATE.
1 Aluminum, . .	Al	IV, $(Al)_2$ vi	2.5	27.11	26.91	+
2 Antimony, . . (Stibium)	Sb	III, V	6.7	120.43	119.52	—
3 Argon, . . .	A	(?)	D* = 19.9	39.8 (?)	(?)	
4 Arsenic, . . .	As	III, V	{ 5.8 { gas 150	75.01 (L = 13.44)†	74.44	—
5 Barium, . . .	Ba	II	4.0	137.43	136.39	+
6 Beryllium, . . (Glucinum)	Be	II	2.15	9.08	9.01	
7 Bismuth, . . .	Bi	III, V	9.8	208.11	206.54	+
8 Boron, ...	B	III	2.63	10.95	10.86	—
9 Bromine, . .	Br	I, III, V, VII	{ 3.2 { D=79.34	{ 79.95 { (L = 7.17)	79.34	—
10 Cadmium, . .	Cd	II	{ 8.6 { D = 56	111.95	111.1	+
11 Cæsium, . . .	Cs	I	. .	132.89	131.89	+
12 Calcium, . . .	Ca	II	1.57	40.07	39.76	+
13 Carbon, . . .	C	II, IV	{ D. 3.3 { G. 2.3	12.01	11.92	—
14 Cerium, . . .	Ce	II, IV (Ce_2) vi	6.62	140.2	139.1	+
15 Chlorine, . .	Cl	I, III, V, VII	35.5	35.45	35.18	—
16 Chromium, . .	Cr	II, IV, (Cr_2) vi	6.8	52.14	51.74	—
17 Cobalt, . . .	Co	II, IV, $(Co)_2$ vi	8.9	58.53	58.49	+
18 Columbium, . (Niobium)	Cb	V	. .	93.73	93.02	—
19 Copper, . . .	Cu	II, $(Cu)_2$ II	8.9	63.6	63.12	+
20 Erbium, . . .	E	II, (Er_2) vi	. .	166.32	165.06	+
21 Fluorine, . .	F	I	19.0	19.06	18.91	—
22 Gadolinium, .	Gd			156.76	155.57	+
23 Gallium, . . .	Ga	III, (Ga_2) vi	6.0	69.91	69.38	+
24 Germanium. .	Ge	II, IV	5.5	72.48	71.93	
25 Gold (Aurum), .	Au	I, III	19.3	197.23	195.74	+
26 Helium, . . .	He		D = 2.18	(?)	(?)	
27 Hydrogen (or Hydrogenium)	H	I	D = 1	{ 1.008 { (L=.0899 gm)	1.0	+
28 Indium, . . .	In	II, (In_2) vi	7.4	113.85	112.99	+
29 Iodine, . . .	I	I, III, V, VII	{ D =125.9 { 4.9	{ (L = 10.38) { 126.85	125.89	—
30 Iridium, . . .	Ir	II, IV, VI	21.1	193.12	191.66	+
31 Iron (Ferrum), .	Fe	II, IV, (Fe_2) vi	7.8	56.02	55.6	+
32 Lanthanum, .	La	III	6.1	138.64	137.59	+
33 Lead, ... (Plumbum)	Pb	II, IV	11.3	206.92	205.36	+
34 Lithium, . . .	Li	I	0.6	7.03	6.97	+
35 Magnesium, .	Mg	II	1.7	24.28	24.1	+
36 Manganese, .	Mn	II, IV, (Mn_2) vi	8.0	54.99	54.57	+

* D = Density of gas or vapor.   † L = Weight of one liter of vapor or gas.
‡ See "Jour. Amer. Chem. Soc.," May, 1897, p. 359.

Name.	Symbol.	Equivalence.	Specific Gravity.	Atomic Weight. O = 16.	Atomic Weight. H = 1	Electrical State.
37 Mercury (Hydrargyrum)	Hg	(Hg_2) II, II	13.6 (D = 100)	200.0 (L = 8.99)	198.49	+
38 Molybdenum,	Mo	*II*, *IV*, VI	8.6	95.99	95.26	—
39 Neodymium, .	Nd	II	. .	140.8	139.7	+
40 Nickel, . . .	Ni	II, *IV*, (Ni_2) VI	8.8	58.69	58.24	+
41 Nitrogen, . .	N	*I*, III, V	14.0	14.04	13.93	+
42 Osmium, . . .	Os	*II*, IV, *VI*, *VIII*	21.4	190.99	189.55	+
43 Oxygen, . . .	O	II	16.0	16.0 (L=1.439)	15.88	—
44 Palladium, . .	Pd	*II*, IV	11.16	106.36	105.56	+
45 Phosphorus, .	P	III, V	2.2 1.83 (D = 62)	31.02	30.79	—
46 Platinum, . .	Pt	*II*, IV	21.5	194.89	193.41	+
47 Potassium (Kalium) . .	K	I	0.86 (D = 39.1)	39.11 (L = 3.5)	38.82	+
48 Praseodymium,	Pr	II	. .	143.6	142.5	+
49 Rhodium, . .	Rh	*II*, IV	11.0	103.01	102.23	+
50 Rubidium, . .	Rb	I	. .	85.43	84.78	+
51 Ruthenium, .	Ru	*II*, IV, *VI*, VIII	11.4	101.68	100.91	+
52 Samarium, . .	Sm	III, V	. .	150.26	149.13	
53 Scandium, . .	Sc	III, (Sc_2) VI	. .	44.12	43.78	
54 Selenium, . .	Se	II, *IV*, *VI*	4.8	79.02	78 42	—
55 Silicon, . . .	Si	*II*, IV	2.6	28.4	28.18	—
56 Silver, ... (Argentum)	Ag	I	10.5	107.92	107.11	+
57 Sodium (Natrium) . .	Na	I	0.97 (D = 23)	23.05 (L = 2.06)	22.88	+
58 Strontium, . .	Sr	II, *IV*	2.54	87.61	86.95	+
59 Sulphur, . . .	S	II, IV, VI	2.0 (D =32)	32.07 (L = 2.86)	31.83	—
60 Tantalum, . .	Ta	III, V	10.78	182.84	181.45	—
61 Tellurium, . .	Te	II, *IV*, *VI*	6.6	127.49	126.52	—
62 Terbium, . .	Tb	III	. .	160.0	158.8	+
63 Thallium, . .	Tl	I, *III*	11.8	204.15	202.61	+
64 Thorium, . .	Th	IV	7.9	232.65	230.87	+
65 Thulium,	Tu		. .	170.7	169.4	+
66 Tin (Stannum)	Sn	*II*, IV	7.3	119.05	118.15	+
67 Titanium, . .	Ti	*II*, IV	. .	48.15	47.79	—
68 Tungsten, . . (Wolfram)	W	II, *IV*, VI	17.6	184.83	183.43	—
69 Uranium, . .	U	II, IV, (Ur_2) VI	18.4	239.59	237.77	+
70 Vanadium, . .	V	III, V (V_2) VI	. .	51.38	50.99	—
71 Ytterbium, . .	Yb	III	. .	173.19	171.88	
72 Yttrium, . . .	Yt	III	4.8	89.02	88.35	+
73 Zinc, ...	Zn	II	7.0 (D = 32.5)	65.41	64.91	+
74 Zirconium, . .	Zr	*II*, IV	4.1	90.4	89.72	+

NOTE.—A number of elements have been announced within the past few years whose names do not appear in this table. Some of them have already been found to be compounds, and others will probably be found to be such when further studied.

PROPERTIES OF MOLECULES.

Molecular Weights.—Molecules, whether elemental or compound, must have a definite size and weight. The absolute weight of molecules and atoms is of no practical value to the chemist, but the comparative weights of molecules we shall find to be of vast importance. The physical properties of bodies—as color, hardness, ductility, etc.—are determined by the properties of the molecules composing them. In weighing molecules we use the lightest known atom as the unit of weight. This atom is that of hydrogen. The relative weights of molecules have all been measured, and in expressing these weights our numbers express how many times heavier the molecule is than the hydrogen atom. Thus, the molecular weight of oxygen is 32 ; * that is, the molecule of oxygen weighs as much as 32 atoms of hydrogen.

Molecular weight, then, is the weight of a molecule as compared with the weight of the hydrogen atom taken as 1.

Avogadro's or Ampère's Law.—This law was first enunciated by Avogadro, an Italian physicist, in 1811, and was reproduced by Ampère, a French physicist, in 1814. The law has already been stated (see p. 28), as follows: **Equal volumes of all true gases, when at the same temperature and under the same pressure, contain the same number of molecules.** That is to say, a liter of any given gas, under the same conditions of temperature and pressure, always contains the same number of molecules, whatever the nature or composition of the molecules composing the gas. As a natural conclusion from this law, we have the following: **First. Gaseous molecules always occupy the same space**—*i. e.*, the molecule, together with the intervening space, always occupies the same volume. **Second.** Since the same volume contains the same number of molecules, it follows that **the weights of equal volumes of any two gases** (under like conditions as above) **are the weights of the same number of molecules. Hence, the two weights will stand in the same proportion to each other as the weights of their respective molecules.**

Thus, suppose equal volumes of hydrogen and oxygen gases, large enough to contain 10,000 molecules each ; the weights of these gases will be in the one case 10,000 times the weight of one molecule of hydrogen, and in the other 10,000 times the weight of one molecule of oxygen, and these numbers must be to each other as the weight of one molecule of hydrogen to one molecule of oxygen. This law is the basis of many of our modern chemical notions. It is to chemistry what Newton's

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* The exact molecular weight of oxygen is 31.76, or twice the atomic weight. (See table, p. 86.)

law of gravitation was to the science of astronomy. This is not the place to enter into the discussion of the proofs of this law. Suffice it to say that it rests on about as strong proof as any other law of physics or chemistry, or as the law of gravitation itself.

If we accept the **mechanical** theory of gases as given on pages 25 and 29, the law of Avogadro is capable of mathematical proof. The evidence in its favor has become so strong that it is now accepted by nearly all chemists as a fact.

Number of Atoms in Elemental Molecules.—We may determine the number of atoms in many elemental molecules by a simple application of Avogadro's law to well-known experiments.

This demonstration may be illustrated by reference to the behavior of the two gases, chlorine and hydrogen.

Into a test-tube inverted over mercury, put equal volumes of the two gases, and allow the apparatus to stand in diffused light. After some hours the greenish color of the mixture will have entirely disappeared, the gases having combined to form the colorless hydrochloric acid. The mercury stands at the same height in the tube as at the beginning of the experiment. The volume of the hydrochloric acid is therefore just equal to the combined volume of both constituents. (See p. 126.)

Let the following diagram represent this combination :

H	+	Cl	=	H Cl
1000	+	1000	=	2000
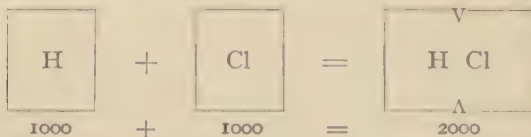
Since the volume of the hydrogen and that of the chlorine are equal, it is clear, from the law of Avogadro, that the number of molecules of each must be the same ; also, that the number of molecules of the hydrochloric acid gas must be equal to the sum of the molecules of the two gases used. Suppose, for illustration, that the volume of hydrogen taken contained 1000 molecules; then there were 1000 molecules of chlorine and 2000 molecules of hydrochloric acid, the volume of this gas being twice that of hydrogen. Each of the 2000 molecules of hydrochloric acid must contain at least an atom of hydrogen and one of chlorine ; hence, 2000 atoms of each of these elements have been derived from 1000 molecules of the same, and therefore each molecule must have furnished at least two atoms.

Experiments quite as decisive have been made to show that in water two volumes of hydrogen and one volume of oxygen produce only two volumes of water-vapor. (See p. 137.) Thus :

H	H	+	O	=	H₂ O
2000		+	1000	=	2000
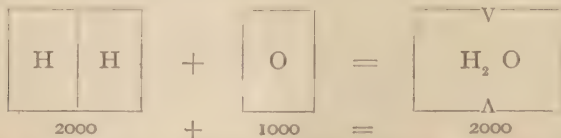
Suppose the volume of oxygen taken contained 1000 molecules. If this volume combined with twice its volume of hydrogen, then 1000

molecules of oxygen combined with 2000 molecules of hydrogen. The volume of steam produced, being the same as that of the hydrogen used, contained the same number of molecules, or 2000 molecules. By the above experiment it was shown that each of the 2000 molecules of hydrogen contained two atoms, and hence there entered into this reaction 4000 atoms. Each of the 2000 molecules of steam must, therefore, have received two atoms of hydrogen.

As 1000 molecules of oxygen have entered into the formation of 2000 molecules of water, each molecule of oxygen must have furnished at least two atoms. Each molecule of water must, therefore, contain *two* atoms of hydrogen to one of oxygen, instead of *one*, as was formerly taught.

Most of the molecules of elemental substances contain two atoms; or, in other words, are diatomic. Argon, mercury, cadmium, zinc, and barium, however, contain but one atom in each molecule. Oxygen, as **ozone**, contains three atoms. Phosphorus and arsenic contain four atoms, but at a white heat these break up into simpler molecules. Sulphur at lower temperatures seems to contain six, while at higher temperatures it contains only two.

Some molecules which at ordinary temperatures contain two atoms break up, or dissociate, as it is termed, at very high temperatures. Thus chlorine, bromine, and iodine, which at a moderate heat are diatomic, at a very high temperature (800° C.) begin to dissociate, and become monatomic at the strongest furnace heat. Many compounds do the same thing. (Hg_2Cl_2, N_2O_2, N_2O_4.) The law of Ampère, therefore, is true only at moderate temperatures.

Molecular Weight, Determined by the Law of Avogadro.— It has just been shown that the molecule of hydrogen is composed of two atoms. We have already defined molecular weight as the weight of a molecule in units of hydrogen atoms. It may also be defined as the sum of the weights of its constituent atoms. The molecular weight of hydrogen is therefore $1 + 1$, or 2. Suppose, for example, we weigh equal volumes of hydrogen and oxygen gases under like conditions of temperature and pressure, and find the weights to be respectively 1 and 16 gm. It follows that the molecules of these gases are to each other as 1 to 16, for, according to the law, each contains the same number of molecules. As the molecular weight of hydrogen has been shown to be 2, it follows that the molecular weight of oxygen must be 32, for 32 bears the same ratio to 2 that 16 does to 1. $1 : 16 : : 2 : 32$. From this it will be seen that the molecular weight of oxygen is twice its density—*i. e.*, its specific gravity as compared with hydrogen. The same reasoning applies to all other gases, whether elemental or compound, and we may state this fact as follows: **The molecular weight of any body is**

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twice its density in the gaseous state. The converse of this
statement is also true—viz., the density of a gas is one-half its
molecular weight. For methods of determining molecular weights,
see part IV, pages 308 and 309.

PROPERTIES OF ATOMS.

Definition.—An atom is the smallest conceivable portion of matter.
It is the smallest portion of an element that can enter into the for-
mation of a molecule or take part in a chemical reaction.

The student should strive to clearly comprehend the difference
between a molecule and an atom. The former is a collection of the
latter held together by an attraction called chemism or chemical
affinity. Molecules are destructible; they may be broken up and
their properties destroyed. The atom, on the other hand, is an in-
destructible solid particle, whose properties, so far as we know, are
never destroyed.

Atomic Weight.—Atoms differ from one another in their weight,
and in the quality and quantity of their combining power. Further
than this we have no certain knowledge of their properties.

The weight of an atom of any given element is always the same. In
weighing atoms we do not take the absolute weight, but the relative
weight, using the hydrogen atom as the unit. The atomic weight
of any element expresses the number of times its atom is heavier than
the atom of hydrogen. The atomic weight of oxygen is 15.88—i. e.,
the atom weighs 15.88 (approximately 16) times as much as the atom
of hydrogen. The atomic weights of the elements will be found in the
table, pages 85 and 86.*

Quality of Combining Power.—Polarity of the Atoms.—We
have seen (p. 76) that when a current of electricity is sent through a
solution of a metallic salt, the metal collects about the negative elec-
trode, while the non-metallic part of the salt appears at the positive.
Such a process of decomposition is called electrolysis. The con-
ducting liquid is called an electrolyte. The poles of the battery
introduced into the electrolyte are called the electrodes, the negative
being called the cathode and the positive the anode.

Most metallic compounds are capable of decomposition by elec-
trolysis, and the molecule seems to be divided into two parts, one of
which is attracted to the positive and the other to the negative elec-
trode. We have seen (p. 53) that two bodies similarly polarized

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* For a description of the methods of determining the value of the atomic weights,
the student is referred to one of the larger hand-books.

repel each other, while bodies oppositely polarized attract each other. We conclude, therefore, that those atoms which are attracted by the negative electrode of the galvanic battery are positively polarized, while the others are negatively polarized. This is what is meant by the difference in the quality of combining power. Positive and negative, as applied to the polarity of atoms, is not absolute, but relative ; and the polarity of an atom may be changed, by the inducing action of another atom, from positive to negative and *vice versâ*. The primary products of electrolysis are called **ions.** As the positive ions appear at the negative electrode, or cathode, they are sometimes called the **cathions,** and the negative ions, which appear at the anode, are termed **anions.** As a general rule, the metallic atoms are positive and the non-metallic negative.

When several atoms are brought into contact with one another, those having a similar polarity repel one another, as do other bodies that are of like polarity, while those having a different polarity attract one another ; hence, union or combination can only take place between atoms that are unlike in their electrical polarity.

In the following table the elements are so placed that each one is electronegative to those below and electropositive to those above it. In this table, silicon and those which follow it are positive to titanium, and iron is positive to nickel :

ELECTROCHEMICAL SERIES.

Negative End —.	*Negative End —.*	*Negative End —.*
Oxygen.	Silicon.	Iron.
Sulphur.	Hydrogen.	Zinc.
Nitrogen.	Gold.	Manganese.
Fluorine.	Osmium.	Lanthanum.
Chlorine.	Iridium.	Didymium.
Bromine.	Platinum.	Cerium.
Iodine.	Rhodium.	Thorium.
Selenium.	Ruthenium.	Zirconium.
Phosphorus.	Palladium.	Aluminum.
Arsenic.	Mercury.	Erbium.
Chromium.	Silver.	Yttrium.
Vanadium.	Copper.	Glucinum.
Molybdenum.	Uranium.	Magnesium.
Tungsten.	Bismuth.	Calcium.
Boron.	Tin.	Strontium.
Carbon.	Indium.	Barium.
Antimony.	Lead.	Lithium.
Tellurium.	Cadmium.	Sodium.
Tantalum.	Thallium.	Potassium.
Columbium.	Cobalt.	Rubidium.
Titanium.	Nickel.	Cæsium.
Positive End +.	*Positive End +.*	*Positive End +.*

Quantity of Combining Power.—By an analysis of a large number of compounds of hydrogen with other elements, it has been found that while chlorine combines with it in the proportion of its atomic weight,—*i. e.*, 1 part by weight of hydrogen to 35.5 parts of Cl,—

16 parts of Oxygen combine with 2 parts of H,
14 "   " Nitrogen   "   "   3 "   " H,
12 "   " Carbon   "   "   4 "   " H,

and so on ; so that the power of the atoms to attract and combine with hydrogen is not alike in all cases. This is expressed by saying that the **equivalence,** or **quantivalence,** of the atom in question is 1, 2, 3, 4, 5, 6, or 7, according as it will attach to itself, be exchanged for, or take the place in a molecule of 1, 2, 3, 4, 5, 6, or 7 atoms of hydrogen or their equivalents.

The chemical equivalent of an atom is an atom which can take its place in a molecule. Atoms are divided into monads, dyads, triads, tetrads, pentads, hexads, or heptads, according as they can fix 1, 2, 3, 4, 5, 6, or 7 atoms of hydrogen or their equivalents. Univalent, bivalent, trivalent, etc., are adjectives used to express the valence of an atom.

A monad is equivalent to a monad.
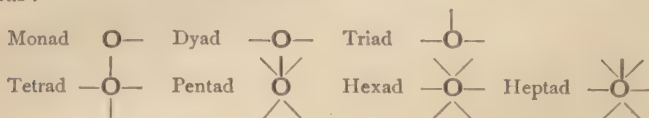 " dyad   "   "   to 2 monads.
 " triad "   "   to 3 monads, or 1 monad and 1 dyad.
 " tetrad "   "   to 4 monads, 2 dyads, or 1 monad and 1 triad.
 " pentad "   "   to 5 monads, a tetrad and 1 monad, a triad and 2 monads,
                        or 2 dyads and 1 monad.

The valence of an atom is often indicated to the eye by dashes, thus :

Monad   O—   Dyad   —O—   Triad   —O—

Tetrad —O—   Pentad   O   Hexad —O—   Heptad —O—

It will be seen that the hydrogen atom is the unit of comparison for combining powers, or valences, and the dashes represent the number of **bonds** or **points of attraction,** or **poles** of the **atomic magnet.** The valence of an atom may also be expressed by a Roman numeral placed above and to the right, thus : H^I, O^{II}, N^{III}, C^{IV}, etc.

CHEMICAL NOTATION.

Symbols and Formulæ.—In representing atoms and molecules to the eye, we make use of a series of symbols derived from the names of the elements themselves. This is usually the initial letter of the English or Latin name, or, in case two or more names begin with the same letter, the initial with some other characteristic letter. Thus, on reference to the table on page 85, we see B, Ba, Bi, Br representing the atoms of boron, barium, bismuth, and bromine respectively. In this book a symbol is not used to represent the element in general, but a symbol always represents an atom, with all its properties, and nothing else.

Formulæ.—A formula is the sign of a molecule. It therefore represents a definite weight—the molecular weight; and, in the case of gases, always the same volume. Formulæ are made up of symbols, as a molecule is made up of atoms; and the atoms composing a molecule are all represented by symbols in the formula. Thus, HCl is a formula representing a molecule containing one atom or one part of hydrogen, and one atom or 35.5 parts by weight of chlorine.

In writing formulæ, we write the symbols composing the molecule in juxtaposition, beginning with the more electropositive. Thus: KOCl, HBr, etc.

Multiplication of Molecules and Atoms.—When we wish to represent more than one atom, we use a small numeral at the right-hand lower corner of the symbol; thus, O_2 represents two atoms of oxygen, or, since the molecule of oxygen contains two atoms, this also represents the molecule. As_4 represents four atoms of arsenic, or, since the molecule of arsenic contains four atoms, it is also the formula of a molecule of arsenic.

When we wish to represent more than one molecule of a substance, we use full-sized numerals, placed before the formula. Thus, $2H_2O$ represents two molecules, each of which is composed of two atoms of hydrogen and one of oxygen. Or, we may inclose the formula in a parenthesis and place a small numeral at the right-hand lower corner, thus: $(H_2O)_2$. Examples:

H_2SO_4 represents 1 molecule, containing 2 atoms of hydrogen, 1 of sulphur, and 4 of oxygen.

$5H_2SO_4$ represents 5 molecules of the same substance.

$3NH_4NO_3$ represents 3 molecules, containing in each molecule 2 atoms of nitrogen, 4 atoms of hydrogen, and 3 atoms of oxygen; 27 atoms in all.

$2K_2Al_2(SO_4)_4$ represents 2 molecules, containing in each molecule 2 atoms of potassium, 2 atoms of aluminum, 4 atoms of sulphur, and 16 atoms of oxygen; 48 atoms in all.

As the symbols always represent the atomic weights, we may reduce any formula to figures, or find its molecular weight, by adding together the weights represented by the symbols composing it. Let it be desired to find the molecular weight of H_2SO_4. By reference to the table on page 85, it will be seen that $H_2 = 2$, $S = 32$, and $O_4 = 4 \times 16 = 64$. By adding together these three numbers we obtain 98, the weight of the molecule.

An **empirical formula** is one which merely gives the kind and number of the atoms composing a molecule. A **rational, structural,** or **graphic formula** aims to show the arrangement of the atoms in the molecule, with relation to one another.

Examples of empirical formulæ :

HNO_3, H_2SO_4, $CuSO_4$, Na_2CO_3, H_3PO_4, CH_4, C_2H_5OH, CO_2.
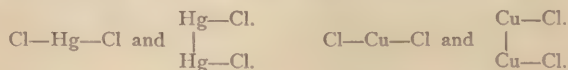
Rational formulæ for the same :
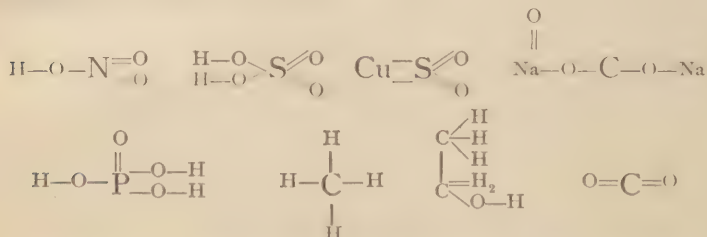
Rational formulæ are useful in giving us a more definite conception of the relation of the atoms to one another in the molecule. They have served as the guides in some of the most important chemical discoveries of the present century ; such as the discovery of the process of manufacturing artificial madder and indigo by synthesis from coal-tar products.

Variation in Valence.—By graphic formulæ we are able to explain a fact that is always a matter of difficulty to the student—viz., the variation in the valence of atoms.

There are two well-known series of salts of mercury and copper in which there is no real variation in valence ; but, owing to the uniting of two atoms of the metals, each loses an available bond or point of attraction. The following formulæ will render this clear :

$$Cl—Hg—Cl \text{ and } \begin{array}{l} Hg—Cl. \\ | \\ Hg—Cl. \end{array} \qquad Cl—Cu—Cl \text{ and } \begin{array}{l} Cu—Cl. \\ | \\ Cu—Cl. \end{array}$$

In other cases, and under certain well-known conditions which we

can control in the laboratory, the atom which has previously existed as a dyad suddenly becomes a tetrad, or a triad becomes a pentad, and so on.

These changes are always extremely puzzling to the student, and we shall dwell a little upon them. When ammonia gas (NH_3), for example, is absorbed by water, it combines with a molecule of the water and becomes NH_4OH. If we represent the two molecules graphically, we have:

$$N\begin{matrix}-H \\ -H \\ -H\end{matrix} \quad \text{and} \quad H-O-\ H-N\begin{matrix}-H. \\ -H. \\ -H.\end{matrix}$$
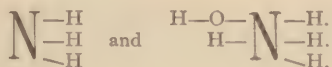
As will be seen, two new points of attraction have made their appearances upon the nitrogen atom. A large number of such cases are known, and the explanation is as follows:

The full valence of nitrogen is pentad. In the compound H_3N, for some unknown reason, two poles of the atomic magnet neutralize each other, and so the combining power of the atom is lessened by two. This increase or diminution of combining power always takes place in pairs, so that a dyad may become a tetrad, but not a triad. A monad may become a triad or a pentad, but never a dyad or tetrad.

Other Signs Used in Writing.—A **plus sign** between two formulæ indicates that the substances whose molecules they represent are brought together.

The **minus sign** indicates that the molecule following it is abstracted from the preceding one. The **sign of equality** is used to indicate that what follows is the result of some change that has taken place. $HCl + AgNO_3 = HNO_3 + AgCl$. This equation shows that the molecules represented by the first two formulæ have been brought together, and that a change has taken place resulting in the formation of the two last.

Compound Radicals.—A **radical** or root of a series of compounds is a characteristic atom or group of atoms running through all of them, like a **root** in language. Thus, the interrogative root **wh** runs through all that class of words, as **who, which, when, what,** etc. So in chemical compounds we have a large number of potassium compounds, in which the atom K appears as the characteristic atom: As, KNO_3, $KClO_3$, K_2CO_3, K_2SO_4, and KCl. It is therefore called the root or radical of these compounds. A single atom which forms a series of characteristic compounds is called a **simple radical.** In most inorganic compounds the radicals may be regarded as identical with the electrical **ions** (see p. 91); that is, the radi-

cals are believed to be dissociated when the substance is in dilute solution, and they may be collected at the opposite electrodes by an electrical current.

Sometimes the radical found to be characteristic of a series of compounds is a group of atoms instead of a single atom. Thus, we have: $(NH_4)NO_3$, $(NH_4)Cl$, $(NH_4)NO_2$, $(NH_4)_2S$, etc., in which the characteristic radical is a group of atoms, or is a **compound radical.**

A compound radical may be regarded as a group of atoms which behaves like a simple radical or single atom. Like the single atom, it exists only in combination with another atom or group of atoms, except in very dilute solutions, for its bonds or points of attraction are not satisfied unless it be in combination. Compound radicals or ions, like atoms, may be positive or negative. Each compound radical has a definite valence, like the atoms. Some of them have received arbitrary names, which may or may not express their composition, and in most cases end in yl. Thus, $(PO)'''$ phosphoryl, $(H \cdot O-)'$ hydroxyl, $(CO)''$ carbonyl, $(CH_3)'$ methyl, $(C_2H_5)'$ ethyl, $(H_4N)'$ ammonium, $(CN)'$ cyanogen, $(NH_2)'$ amidogen. The last three are exceptions to the rule as to the ending.

In writing the formula of these compound radicals, they may be regarded for the time as atoms of a compound nature. If we wish to represent that several similar compound radicals enter into the same molecule, we inclose the formula in a parenthesis, and, as with atoms, use the numerals, thus: $(NH_4)_2CO_3$, $Fe_2(OH)_6$.

In the following table will be found the more important elements, arranged according to both quality and quantity of combining power. The elements at the top of the table are negative to all below them ; and those at the bottom are positive to all above. They are also divided into monad, dyad, triad, etc., some appearing in two or even three columns, because of their change in valence. In the second table will be found the more common atomic groups, with the names of the classes of compounds they form, arranged, as far as possible, in the same order as the elements. In regard to their electrical polarity, less certainty exists than with the elements.

VALENCE OF THE MOST IMPORTANT ELEMENTS.

MONADS.	DYADS.	TRIADS.	TETRADS.	PENTADS.	HEXADS.
Fluorine, . F Chlorine, Cl Bromine, Br Iodine, . . I Hydrogen, H Silver, . Ag Sodium, Na Potassium, K	Oxygen, . . O Sulphur, . . S Mercury, Hg Copper, . Cu Lead, . . . Pb Cadmium, Cd Cobalt, . . Co Nickel, . . Ni Iron, . . . Fe Chromium, Cr Manganese, Mn Zinc, . . . Zn Magnesium Mg Calcium, . Ca Strontium, Sr Barium, . Ba	Nitrogen, . N Phosphorus, P Arsenic, . As Boron, . . . B Antimony, Sb Gold, . . . Au Bismuth, Bi	Sulphur, . . S Carbon, . . C Silicon, . . Si Platinum, . Pt Tin, . . . Sn Iron, . . . Fe Chromium, Cr Manganese, Mn Aluminum, Al	Nitrogen, N Phosphorus, P Arsenic, . As	Sulphur, . . S Chromium, Cr Manganese, Mn

CHARACTERISTIC GROUPS OF ATOMS WITH NAMES OF COMPOUNDS THEY FORM.

MONADS.	DYADS.	TRIADS.	TETRADS.
NO_3 = Nitrates ClO_3 = Chlorates NO_2 = Nitrites ClO = Hypochlorites PH_2O_2 = Hypophosphites CN = Cyanides $C_2H_3O_2$ = Acetates $C_7H_5O_2$ = Benzoates $C_7H_4O_3$ = Salicylates C_6H_5O = Carbolates $C_3H_5O_3$ = Lactates HO = Hydroxides NH_4 = Ammonium CH_3 = Methyl C_2H_5 = Ethyl	SO_4 = Sulphates CrO_4 = Chromates Cr_2O_7 = Bichromates SO_3 = Sulphites C_2O_4 = Oxalates $C_4H_4O_6$ = Tartrates $C_4H_4O_5$ = Malates CO_3 = Carbonates Hg_2 = Mercurous Salts Cu_2 = Cuprous Salts	PO_4 = Phosphates AsO_3 = Arsenites AsO_4 = Arsenates BO_3 = Borates $C_6H_5O_7$ = Citrates	SiO_4 = Silicates P_2O_7 = Pyrophosphates $FeCy_6$ = Ferrocyanides <hr>**HEXADS.** Fe_2Cy_{12} = Ferricyanides Al_2 = Aluminic Salts Cr_2 = Chromic " Mn_2 = Manganic " Fe_2 = Ferric "

COMPOUND MOLECULES.

Compound Molecules Classified.—The system of nomenclature now in use for naming chemical compounds is based upon the composition and properties of the bodies in question; and the name of the body is intended to express our idea of its chemical composition. Homogeneous bodies are supposed to be made up of a collection of similar molecules; hence, a formula which represents the composition of a single molecule really represents the composition of the mass. In applying names to compounds, we apply the name to the molecule as well as to the mass.
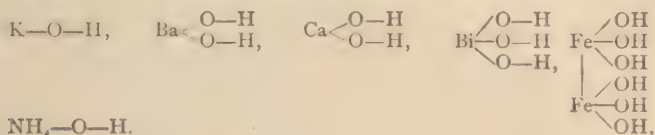
Compound bodies may be divided into two classes: (1) Those whose molecules are composed of two kinds of atoms or radicals, called **binary compounds**; and (2) those whose molecules are composed of three or more kinds of atoms or radicals, called **ternary molecules.** Examples: $NaCl$, KBr, $MgCl_2$, and $(NH_4)Cl$ are examples of binary molecules. $KClO_3$, K_2SO_4, $CaCO_3$, $(NH_4)NO_3$, and $Ba(NO_3)_2$ are examples of ternary molecules.

Acids, Bases, and Salts.—Ternary molecules are divided into **acids, bases,** and **neutrals** or **salts.** An **acid** is a substance which usually possesses a sour taste, corrodes the metals with the evolution of hydrogen and the formation of salts, changes blue vegetable colors to reds, and neutralizes the caustic properties of alkalies by forming salts with them. All acids contain hydrogen, which can be replaced by a metal. This hydrogen is united to the remaining portion of the molecule, either directly, as in binary acids, or by a linking atom, usually oxygen, as represented by the following graphic formulæ:

$$H—Cl, \qquad \begin{matrix} H—O \\ H—O \end{matrix} S \begin{matrix} O \\ O \end{matrix}, \qquad H—O—N \begin{matrix} O \\ O \end{matrix}.$$
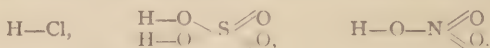
The replaceable hydrogen of an acid is called **basic hydrogen,** and the number of such atoms determines the **basicity** of the acid. A dibasic acid, for example, is one containing two atoms of basic hydrogen, a tribasic acid three, a tetrabasic acid four, and so on. When the linking atom of these ternary acids is oxygen, the name **oxacids** is applied to them. The term **sulpho-acids** is applied to those containing linking sulphur. A **base** has properties which in many respects are opposed to and neutralize the effects of acids. They restore the vegetable blue colors reddened by acids, they neutralize the sour taste, and they react upon acids to form salts, with the elimination of water. The strong bases have a caustic action upon the tissues, and decompose the fats, with which they form soaps.

A **base** may be defined as a compound whose molecule is composed of a positive atom, or group of atoms, united by linking oxygen to hydrogen.* The positive atom is metallic in inorganic bases. As:

$$K—O—H, \quad Ba{<}{\overset{O—H}{\underset{O—H}{}}}, \quad Ca{<}{\overset{O—H}{\underset{O—H}{}}}, \quad Bi{\overset{O—H}{\underset{O—H,}{—O—H}}} \quad Fe{\overset{OH}{\underset{OH}{—OH}}}$$

$$Fe{\overset{OH}{\underset{OH,}{—OH}}}$$

$$NH_4—O—H.$$

In the last formula we have an example of a compound radical united to H by O. The inorganic bases are named **hydroxides.**

A **salt** molecule is composed of a positive radical united by linking oxygen to a negative radical. The radicals, in this case, as in acids and bases, may be either simple or compound. Thus:

$$K—O—Cl, \ K—O—NO_2, \ Na_2 \quad O_2 = CO, \ Ba = O_2 = SO_2, \ (NH_4)—O—NO_2.$$
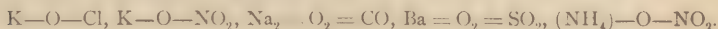
It is evident, also, that a salt may be formed by treating an acid with a metal, which replaces the hydrogen of the acid with metallic atoms.
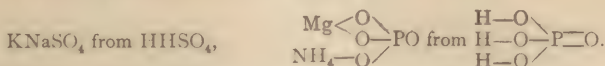
$$Zn + (H_2 = O_2 = SO_2) = (Zn \quad O_2 = SO_2) + HH.$$
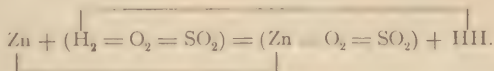
It may be regarded, then, as an acid whose replaceable hydrogen atoms have been replaced by positive atoms or radicals. In a dibasic acid, like $H—O{\searrow}{\underset{}{S}}{\nearrow}O$ it is possible to replace one of the atoms $H—O{\nearrow}{}{\searrow}O,$ of hydrogen and leave the other undisturbed. We thus have, for example, $H—O{\searrow}{S}{\nearrow}O$ which exhibits the properties and answers to $K—O{\nearrow}{}{\searrow}O,$ the definition of both a salt and an acid. It has acid properties by virtue of the replaceable hydrogen, and saline properties by virtue of the other chain, in which the K has replaced H.

Such a body is called an **acid salt,** while the salts first mentioned, in which all the H atoms have been replaced by positive atoms, are called **normal salts.**

Double salts are formed by replacing a part of the hydrogen of the acid by one positive radical, and a part by another.

$$KNaSO_4 \text{ from } HHSO_4, \qquad {\underset{NH_4—O}{Mg{<}\overset{O}{}}}{\searrow}{\overset{O}{}}PO \text{ from } {\underset{H—O}{\overset{H—O}{H—O}}}{\searrow}P{=}O.$$

---

* This definition applies only to inorganic bases.

If a base or metallic oxide be treated with sufficient acid to neutralize it, a neutral salt is usually formed; but if the base or oxide be much in excess of what the acid would require to expel all its hydrogen, a basic salt will, in some cases, be formed according to the following formulæ:

$$Pb\!<\!^{O-H}_{O-H}, \quad Pb\!<\!^{O-N\,=O}_{O-H}\,^{=O} \quad \text{or} \quad Pb\!<\!^{O-Pb}_{O-N\,=O_2}\!^{O-N\,=O}_{=O}$$
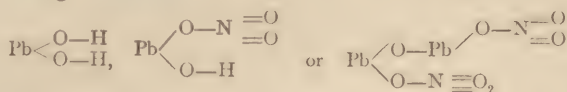
i. e., the acid radical may take the place of a part of its replaceable hydrogen, and leave a part of it; or a part of the excess of oxide may crowd into the molecule between the negative radical and the positive. Such bodies are called **basic salts** or **subsalts.**

The **subsalts** are seldom of definite chemical composition, often being mixtures of the oxide with the basic or normal salt. Lead and bismuth are two metals especially liable to form basic salts.

$$Bi\!^{=O}_{-O-N\,=O}\!_{=O}, \qquad Bi\!^{O}_{-O}\!>\!CO, \qquad Pb\!<\!^{O-(C_2H_3O)}_{O-Pb-O-(C_2H_3O)}.$$
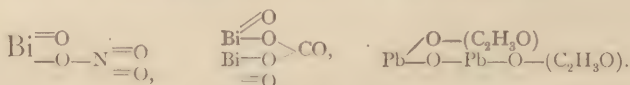
Types of Chemical Compounds.—There are three forms in which atoms group themselves, which are so persistent and characteristic, and to which so many compound molecules conform, that they may be regarded as types or patterns, and are of great use in classifying chemical substances.

These three types are illustrated by the following three graphic formulæ of well-known substances:

H—Cl	H—O—H	$N\!\equiv\!^{-H}_{-H}{}_{-H}$
Hydrogen chloride.	**Water.**	**Ammonia.**
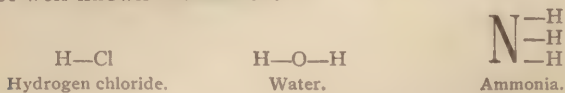
These types or models are generally known as the **hydrochloric acid type**, the **water type**, and the **ammonia type.** The binary compounds mentioned above are constructed on the first type. The ternary acids, bases, and salts are constructed on the second or water type. Arsine, AsH_3, is an example of a compound of the ammonia type.
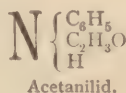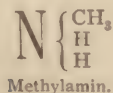
It is in the study of organic compounds that reference to these types is most useful.

In these compounds the compound radicals make the formulæ so complicated that we are obliged to keep in mind the type of structure
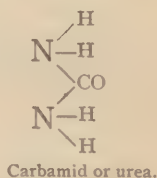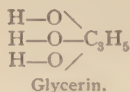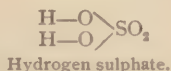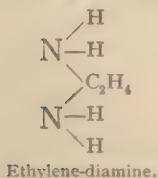
of the molecules to understand their composition. The alcohols, ethers, and organic acids illustrate the use of types.

$$CH_3—OH$$
Methyl alcohol.

$$CH_3—O—CH_3$$
Methyl ether.

$$CH_2O—O—H$$
Formic acid.
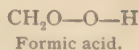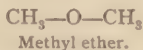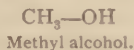
These compounds are all formed on the water type. The following are examples of compounds formed on the ammonia type:

$$N \begin{cases} CH_3 \\ H \\ H \end{cases}$$
Methylamin.

$$N \begin{cases} C_6H_5 \\ H \\ H \end{cases}$$
Phenylamin.

$$N \begin{cases} C_6H_5 \\ C_2H_3O \\ H \end{cases}$$
Acetanilid.

Condensed types may be formed by two molecules, or parts of molecules, being bound together by a bivalent atom or radical. The following are examples of condensed types:

$$\begin{matrix} N \diagup^H_{—H} \\ \diagdown C_2H_4 \\ N \diagup^{—H}_{\diagdown H} \end{matrix}$$
Ethylene-diamine.

$$\begin{matrix} H—O \diagdown \\ H—O \diagup \end{matrix} SO_2$$
Hydrogen sulphate.

$$\begin{matrix} H—O \diagdown \\ H—O—C_3H_5 \\ H—O \diagup \end{matrix}$$
Glycerin.

$$\begin{matrix} N \diagup^H_{—H} \\ \diagdown CO \\ N \diagup^{—H}_{\diagdown H} \end{matrix}$$
Carbamid or urea.

NOMENCLATURE.

Naming of Chemical Compounds.—Rule: Give the name of the positive radical first; then the name of the leading negative atom or radical, with its termination changed to id * or ide in binaries, and to ite or ate in ternaries, ite denoting the lower and ate the higher valence of the negative atom.

EXAMPLES.

NaCl	= Sodium	Chlorid or Chloride,	— binary.
$NaNO_2$ =	"	Nitrite,	— ternary.
$NaNO_3$ =	"	Nitrate,	— "
$BaCl_2$	= Barium	Chlorid or Chloride,	— binary.
$CaBr_2$	= Calcium	Bromid or Bromide,	— "
$BaSO_3$	= Barium	Sulphite,	— ternary.
$BaSO_4$ =	"	Sulphate,	— "

* The final e, in the spelling of the names of the binary compounds, is recommended to be dropped by the rules of the American Association for the Advancement of Science. For these rules, see Appendix. The reasons for retaining the established spelling in this edition will be found in the Preface.

As will be seen on inspection, the valence of the negative atom is indicated by the comparative amounts of oxygen which it holds. Compare $BaSO_3$ and $BaSO_4$; also, $NaNO_2$ and $NaNO_3$. In compounds like the following,—$SnCl_2$, $SnCl_4$, $CuCl_2$, Cu_2Cl_2, $HgCl_2$, Hg_2Cl_2, $FeCl_2$, and Fe_2Cl_6,—where there are more than one valence of the positive atom, the endings **ous** and **ic** are used to distinguish them; thus:

$$
\begin{aligned}
SnCl_2 &= \text{Stann}ous \text{ Chloride, dyad tin.}\\
SnCl_4 &= \text{Stann}ic \quad\text{"}\quad \text{tetrad tin.}\\
CuCl_2 &= \text{Cupr}ic \quad\text{"}\\
Cu_2Cl_2 &= \text{Cupr}ous \quad\text{"}\\
Hg_2Cl_2 &= \text{Mercur}ous \quad\text{"}\\
HgCl_2 &= \text{Mercur}ic \quad\text{"}\\
FeCl_2 &= \text{Ferr}ous \quad\text{"}\quad \text{dyad iron.}\\
Fe_2Cl_6 &= \text{Ferr}ic \quad\text{"}\quad \text{tetrad iron.}
\end{aligned}
$$

When more than two valences are known, we employ the prefix **per** to denote a valence higher than that expressed by **ic** or **ate**, and **hypo** to denote a lower than that expressed by **ous** or **ite**. They are prefixed alike to positive and negative radicals.

EXAMPLES.

$$
\begin{aligned}
N_2O &= \text{Nitrous oxid or oxide.}\\
N_2O_3 &= \text{Nitric } \quad\text{"} \quad\text{"}\\
N_2O_4 &= \text{Nitric peroxid or tetroxid.}\\
Na_2S_2O_3 &= \text{Sodium Hyposulphite.}\\
H_2SO_3 &= \text{Hydrogen Sulphite or Sulphurous acid.}\\
H_2SO_4 &= \quad\text{"} \quad\text{Sulphate or Sulphuric acid.}\\
KClO &= \text{Potassium Hypochlorite.}\\
HClO_2 &= \text{Hydrogen Chlorite or Chlorous acid.}\\
HClO_3 &= \quad\text{"} \quad\text{Chlorate or Chloric acid.}\\
KClO_4 &= \text{Potassium Perchlorate.}\\
Cl_2O &= \text{Hypochlorous oxid or oxide.}
\end{aligned}
$$

The class of bodies which we have called acids are more commonly named in the following manner:

The negative atom, with the prefixes and suffixes usually attached to positive elements, is named first; this is followed by the word **acid,** thus:

$$
\begin{aligned}
HCl &= \text{Hydrochloric acid for Hydrogen Chloride.}\\
HBr &= \text{Hydrobromic " for } \quad\text{"} \quad\text{Bromide.}\\
HI &= \text{Hydriodic " for } \quad\text{"} \quad\text{Iodide.}\\
H_2S &= \text{Hydrosulphuric acid for " Sulphide.}
\end{aligned}
$$

The binary compounds, above mentioned, are called **hydracids** to distinguish them from the **oxacids** or ternary acids; and in the naming of them the prefix **hydro** is used.

EXAMPLES OF OXACIDS.

$HClO$	$=$	Hydrogen	Hypochlorite	or Hypochlorous	Acid.
HNO_2	$=$	"	Nitrite	or Nitrous	"
$HClO_3$	$=$	"	Chlorate	or Chloric	"
HNO_3	$=$	"	Nitrate	or Nitric	"
H_2SO_3	$=$	"	Sulphite	or Sulphurous	"
H_2SO_4	$=$	"	Sulphate	or Sulphuric	"
H_2CO_3	$=$	"	Carbonate	or Carbonic	"

It will be seen that each of the above acids has a characteristic negative group of atoms: thus, in **sulphates** we may always expect the group SO_4''; in a sulphite we will always find the group So_3''; in a nitrate, NO_3'; in a chlorate, ClO_3', etc.

Nomenclature Simplified.—The above rules of nomenclature may be applied much more easily by reference to the table given on page 97.

By the use of this table the student can easily learn to name all the more common compounds. Let it be desired, for example, to name the following formula: $CuSO_4$. Cu is the symbol for **copper.** We next look among the compound radicals and find SO_4 to be the characteristic group of atoms found in all **sulphates.** The name of the formula is, therefore, copper sulphate. What is the formula of zinc carbonate? We find zinc among the dyads, as also the group CO_3 opposite the word carbonates. Both these radicals are dyads, and as a dyad is equivalent to a dyad, they will combine directly, and we have $ZnCO_3$ as the desired formula.

What is the formula of sodium sulphate? The symbol of sodium is Na; it is a monad, while SO_4 is a dyad. Two monads are equivalent to one dyad. Hence Na_2SO_4 is the formula of sodium sulphate. Let it be desired to know the formula of calcium phosphate. Here we wish to combine a triad and a dyad. To do so we must double the triad to get an even number of bonds; we must take, then, three atoms of calcium to get six bonds. The formula will thus be $Ca_3(PO_4)_2$. What is the formula of ferric oxide? In ferric iron two atoms always go together as a hexad. It will require three dyads to saturate the hexad, and we have Fe_2O_3. Stannous chloride will have the formula $SnCl_2$; stannic chloride, $SnCl_4$; mercuric oxide, HgO; mercurous oxide, Hg_2O; and cuprous chloride, Cu_2Cl_2.

Examples for Practice.—We introduce here a series of formulæ for practice in nomenclature, with corresponding names in columns below. The numbers opposite the formulæ will be found opposite the corresponding names below.

1 BaO_2H_2
2 CaC_2O_4
3 $BiCl_3$
4 Na_2CO_3
5 $MgSO_4$
6 $Fe_2(SO_4)_3$
7 $AgNO_3$
8 $(NH_4)Cl$
9 HNO_3
10 Hg_2Cl_2
11 $PbCrO_4$
12 KI
13 K_2O
14 As_2O_3
15 Cu_2FeCy_6
16 $(NH_4)_2S$
17 As_2S_3
18 NH_4MgPO_4
19 $KHCO_3$
20 $SbCl_3$
21 $BiONO_3$
22 $Fe_3(Fe_2Cy_{12})$
23 $K(CN)S$
24 K_2CrO_4

25 $Fe_2(CrO_4)_3$
26 $Al_2(OH)_6$
27 KCy
28 ZnO
29 $SrCO_3$
30 $Sr(NO_3)_2$
31 $BaCl_2$
32 NH_4NO_3
33 $(NH_4)_2CO_3$
34 $KNaSO_4$
35 $NaHCO_3$
36 $Ca_3(PO_4)_2$
37 $Ca(PO_2H_2)_2$
38 $NaClO$
39 Bi_2O_3
40 O_2
41 $KClO_4$
42 $Pb_2O(C_2H_3O_2)_2$
43 $AgCl$
44 $AgBr$
45 NaF
46 NaI
47 KBr
48 $PbCl_2$

49 Fe_2Cl_6
50 $PtCl_4$
51 $AuCl_3$
52 MnO_2
53 K_2MnO_4
54 $Ba(NO_3)_2$
55 $MnSO_4$
56 $PbSO_4$
57 $Cu(C_2H_3O_2)_2$
58 $Ca(C_2H_3O_2)_2$
59 $Ca(OCl)_2$
60 $Fe_2(C_2H_3O_2)_6$
61 $Na(C_7H_5O_3)$
62 $Na(C_7H_5O_2)$
63 $K_2Mn_2O_8$
    or $KMnO_4$
64 $K_2Cr_2O_7$
65 $(NH_4)_2C_2O_4$
66 $CaSO_3$
67 $Ca(C_4H_4O_6)$
68 $Na_2(C_4H_4O_5)$
69 Na_3AsO_3
70 Na_3AsO_4.

1 Barium Hydroxide.
2 Calcium Oxalate.
3 Bismuth Chloride.
4 Sodium Carbonate.
5 Magnesium Sulphate.
6 Ferric Sulphate.
7 Silver Nitrate.
8 Ammonium Chloride.
9 Hydrogen Nitrate. (Nitric Acid.)
10 Mercurous Chloride.
11 Lead Chromate.
12 Potassium Iodide.
13 Potassium Oxide.
14 Arsenous Oxide.
15 Copper Ferrocyanide.
16 Ammonium Sulphide.
17 Arsenous Sulphide.
18 Ammonium Magnesium Phosphate.
19 Acid Potassium Carbonate, or Potassium Bicarbonate.
20 Antimonous Chloride.
21 Bismuth Oxynitrate.
22 Ferrous Ferricyanide.
23 Potassium Sulphocyanate.

24 Potassium Chromate.
25 Ferric Chromate.
26 Aluminic Hydroxide, or Hydrate.
27 Potassium Cyanide.
28 Zinc Oxide.
29 Strontium Carbonate.
30 Strontium Nitrate.
31 Barium Chloride.
32 Ammonium Nitrate.
33 Ammonium Carbonate.
34 Potassium Sodium Sulphate.
35 Hydrogen Sodium Carbonate.
36 Tricalcium Phosphate.
37 Calcium Hypophosphite.
38 Sodium Hypochlorite.
39 Bismuth Oxide.
40 Oxygen.
41 Potassium Perchlorate.
42 Basic Plumbic Acetate.
43 Silver Chloride.
44 Silver Bromide.
45 Sodium Fluoride.
46 Sodium Iodide.

47 Potassium Bromide.
48 Lead Chloride.
49 Ferric Chloride.
50 Platinic Chloride.
51 Gold Chloride.
52 Manganic Oxide.
53 Potassium Manganate.
54 Barium Nitrate.
55 Manganese Sulphate.
56 Lead Sulphate.
57 Copper Acetate.
58 Calcium Acetate.
59 Calcium Hypochlorite.
60 Ferric Acetate.
61 Sodium Salicylate.
62 Sodium Benzoate.
63 Potassium Permanganate.
64 Acid Potassium Chromate. (Potassium Bichromate.)
65 Ammonium Oxalate.
66 Calcium Sulphite.
67 Calcium Tartrate.
68 Sodium Malate.
69 Sodium Arsenite.
70 Sodium Arsenate.

Irregularities in Nomenclature.—In many medical and pharmaceutical works the old style of making the negative precede the positive, with the preposition **of** between them, is still used. In this case **per** is used instead of **ic** or **ate,** and **proto** instead of **ite** or **ous.** These irregularities are becoming obsolete.

EXAMPLES.

	NEW NAME.	OLD NAME.
$SnCl_2$	= Stannous Chloride	or Protochloride of tin.
$SnCl_4$	= Stannic "	or Perchloride of tin.
Fe_2Cl_6	= Ferric "	or Perchloride of iron.
$Fe_2(SO_4)_3$	= " Sulphate	or Persulphate of iron.
Fe_2O_3	= " Oxide	or Per- or Sesquioxide of iron.
Hg_2I_2	= Mercurous Iodide	or Protiodide of mercury.
Hg_2Cl_2	= " Chloride	or Protochloride, mild chloride, or calomel.
$HgCl_2$	= Mercuric Chloride	or Bichloride, corrosive sublimate.
HgO	= " Oxide	or Red oxide of mercury.
Hg_2O	= Mercurous Oxide	or Black oxide or protoxide of mercury.

The **proto**-salts of iron are the **ferrous salts,** while the **per**-salts are the **ferric salts.**

The oxides of the alkaline metals, the earths, and the alkaline earths are sometimes named as follows:

Al_2O_3	Alumina.		CaO	Lime.
MgO	Magnesia.		K_2O	Potassa or Potash.
BaO	Baryta.		Na_2O	Soda.
SrO	Strontia.			

Some writers name those oxides of the non-metallic elements which dissolve in water to form acids, as though they were formed from the acids by abstracting one or more molecules of water.

Thus SO_2 is named Sulphurous Anhydride.
CO_2 " Carbonic "
N_2O_3 " Nitrous "
N_2O_5 " Nitric "
P_2O_5 " Phosphoric "

For, $SO_2 + H_2O = H_2SO_3 =$ Sulphurous Acid.
$CO_2 + H_2O = H_2CO_3 =$ Carbonic "
$N_2O_5 + H_2O = 2HNO_3 =$ Nitric "
$P_2O_5 + 3H_2O = 2H_3PO_4 =$ Phosphoric "
$SO_3 + H_2O = H_2SO_4 =$ Sulphuric "

It is a common custom with some authors to use the numerals di, tri or ter, tetra, and penta to indicate the number of atoms of the element to whose name the numeral is prefixed.

Thus: FeS_2 Ferric Disulphide   or Bisulphide of Iron.
       Fe_2S Diferrous Sulphide   or Sulphide of Iron.
       Fe_2S_3 Ferric Sulphide   or Sesquisulphide of Iron.
       FeS   Ferrous Sulphide   or Protosulphide of Iron.
       CO_2 Carbon Dioxide   or Carbonic Acid.
       PCl_3 Phosphorous Trichloride.
       PCl_5 "   Pentachloride.
       $HgCl_2$ Mercuric Dichloride or Bichloride of Mercury.

A few compounds are known by names which do not express their composition.

Thus: H_3N Ammonia.
       CN   Cyanogen (symbol Cy).
       H_3Sb Antimonuretted Hydrogen or Stibin.
       H_3As Arsenuretted   "   or Arsin.
       H_2S Sulphuretted   "   or Hydrosulphuric Acid.
       H_3P Phosphoretted   "   or Phosphin.
       H_4C Light Carburetted "   or Marsh Gas.
       H_4C_2 Heavy Carburetted "   or Olefiant Gas.

A glossary of obsolete and popular names, and those of some chemical compounds only occasionally met with, will be found in the Appendix.

CHEMICAL REACTIONS AND EQUATIONS.

All material bodies, under certain conditions, may undergo marked changes in properties. As the physical properties of bodies depend upon the properties of their molecules, any great change in these properties must depend upon a corresponding change in the molecules. In a homogeneous mass of matter all molecules are alike : and any chemical change which we are able to produce in one molecule of such a mass may, with certainty, be produced in all. Hence, by representing the changes which take place between two dissimilar molecules, we do, in reality, represent the changes taking place between the masses of which these molecules form a part. It is upon this principle that we represent chemical changes to the eye. When two substances, on being brought together, act upon each other, the mutual action between them is called a **reaction.**

A body which is added to another to cause such a change is called a **reagent.** When a jet of coal-gas is burned in the air, the reagents are the gas and the oxygen of the air. The **results** of the reaction are light and heat. The **products** of the reaction are the watery vapor and carbon dioxide which are produced. The **factors** entering into the reaction are oxygen and the compounds which compose the gas.

While all material molecules are more or less liable to undergo chemical change by the action of external agencies, some do so very readily, while others resist such change with considerable force. Chemical reactions are favored by anything that lessens cohesion or favors the free movement of the molecules; as solution, pulverization, percussion, trituration, heat, light, and electricity.

Reaction between solids is always slow, and, in many cases, entirely wanting. If the solids are brought together in solution, the reaction takes place with readiness; if volatilized, still more readily. Reactions between gases usually take place almost instantaneously throughout the mass, and, in many cases, with an explosion. Heat usually favors chemical action, and cold retards it. Light favors many kinds of chemical change, but does not affect all. Reactions, in the laboratory, are generally conducted in solutions. When the bodies are soluble in water, that liquid is generally selected; if not, some other solvent, such as ether, alcohol, chloroform, etc., is employed.

When two or more substances are brought together in solution, the action that will take place depends largely upon the following conditions, first formulated by Berthollet, and usually known as the **Laws of Berthollet** :

1. When two or more substances are brought together in solution, if by any rearrangement of the atoms a product can be formed which is insoluble in the liquid present, that substance will form and separate as a precipitate.

2. When two substances are brought together in solution, if a gaseous body or one that is volatile at the temperature of the experiment can form, it will form and escape as a gas or vapor.

Illustration.—$BaCl_2 + Na_2SO_4 = ?$ By a rearrangement of these atoms, according to the principles stated on page 108, there can only form $BaSO_4$ and $2NaCl$. The latter of these is soluble in water, while the former is not; hence, $BaSO_4$ will always separate from this mixture.

$Zn + 2HCl = ZnCl_2 + H_2$. Here, by changing the places of the two positives, hydrogen is set free, and escapes.

The above laws apply to insoluble or volatile substances only.

When two acids in solution are made to act upon one base, or two bases upon one acid, to produce soluble non-volatile substances, the base in the first instance divides itself between the two acids, or in the second instance the acid is divided between the two bases. That is, if a solution of sodium hydroxide be treated with an excess of nitric and hydrochloric acids, both sodium nitrate and chloride are produced; or if sulphuric acid be treated with a mixture of sodium and potassium hydroxides more than sufficient to saturate the acid, both

sulphates are produced. The quantities of each salt produced will depend upon the relative quantities of the two acids or two bases present, and upon the relative affinities between the acids and bases.

In diluted solutions of the above compounds, nitric and hydrochloric acids were found to be the strongest of the mineral acids, while hydrobromic, hydriodic, sulphuric, phosphoric, oxalic, and acetic acids follow in the order named. The avidity of nitric and hydrochloric acids for sodium was found to be twice that of sulphuric acid, or, when sodium sulphate is treated with excess of nitric acid, the following reaction takes place :

$$2Na_2SO_4 + 4HNO_3 = Na_2SO_4 + 2NaNO_3 + H_2SO_4 + 2HNO_3.$$

As matter is indestructible, it follows that there can be neither loss nor gain in the weight of the matter taking part in a reaction. The sum of the weights of the factors entering into a reaction must, therefore, be equal to the sum of the weights of the products coming from it. Hence, if we write the sum of the formulæ of the factors equal to the sum of the formulæ of the products of any reaction, it must always form a true equation. In writing out representations of chemical reactions, the student should remember the following rules :

1. **Positives** combine with **negatives** and not with **positives.**

2. Every member of the equation must represent a whole molecule or a number of molecules.

3. The valences of the atoms and radicals must all be saturated according to the rules laid down under **valence**, on page 92.

4. An **acid** and a **base** can not exist in the same solution. They are incompatibles, and neutralize each other.

5. The strongest acids generally select the strongest bases, except in cases where this is modified by Berthollet's laws. Compound radicals, as a rule, remain as such in the products.

To write chemical equations, place the formulæ of the factors, connected by a plus sign, equal to the formulæ of the products, also connected by a plus sign. Now take such a number of molecules as factors that only whole molecules can be produced in the products.

EXAMPLES.

$$\overset{+}{Ag}\,\overset{-}{NO_3} + \overset{+}{Na}\,\overset{-}{Cl} = (?)$$
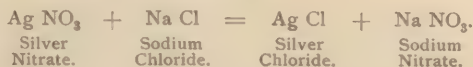Silver Sodium
Nitrate. Chloride.
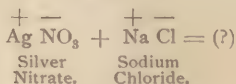
We first determine which are positive and which are negative radicals. The metals are positive, and the non-metallic radicals are negative, as indicated by the signs above the symbols.

We next cause the positive radicals to exchange places, whence we have AgCl and $NaNO_3$.

On referring to the table of equivalences (p. 97), we find all these radicals to be monad, and therefore chemical equivalents.

The completed equation will, therefore, be :

$$Ag\ NO_3 \quad + \quad Na\ Cl \quad = \quad Ag\ Cl \quad + \quad Na\ NO_3.$$

| Silver Nitrate. | Sodium Chloride. | Silver Chloride. | Sodium Nitrate. |

EXAMPLES FOR PRACTICE.

Complete the following :

1. $2Ag\ (NO_3) + H_2S = ?$
2. $Pb\ (NO_3)_2 + H_2S =$
3. $H_2\ (SO_4) + Ca\ O_2\ H_2 =$
4. $KI + Ag\ NO_3 =$
5. $Fe\ Cl_2 + 2KOH =$
6. $Fe_2\ Cl_6 + 6KOH =$
7. $Ni\ (NO_3)_2 + Na_2S =$
8. $Mg\ SO_4 + 2(NH_4)\ OH =$
9. $Ba\ Cl_2 + Na_2\ SO_4 =$
10. $Bi\ Cl_3 + H_2O = Bi\ OCl + ?$
11. $Pb\ (C_2H_3O_2)_2 + H_2\ SO_4 =$
12. $Ba\ Cl_2 + (NH_4)_2\ CrO_4 =$
13. $Na_2\ CO_3 + 2HCl =$
14. $Cu\ SO_4 + 2NaOH =$
15. $Hg_2\ (NO_3)_2 + 2NaCl =$
16. $Mg\ SO_4 + H\ Na_2PO_4 + NH_4OH$

Stochiometry.—Chemical symbols represent definite weights, or atomic weights. Chemical formulæ, therefore, enable us to calculate the percentage of any ingredient in the compounds they represent ; or, from chemical equations, we may calculate the weight of any substance required by any given process, or the exact amounts evolved by it.

These calculations are all based upon the atomic weights. Molecular weights are derived from the atomic weights.

The molecular weight of calcium carbonate, $CaCO_3$, is—

$$(C = 12) + (O_3 = 48) + (Ca = 40) = 100. \quad \text{(See table, p. 85.)*}$$

On inspection, we see that $\frac{40}{100}$ of the whole quantity is calcium, $\frac{12}{100}$ carbon, and $\frac{46}{100}$ oxygen.

Let it be desired to calculate the quantity of hydrogen in one part of water; formula, H_2O :

$$(H_2 = 2) + (O = 16) = 18.$$
$$\tfrac{2}{18} = \text{Hydrogen}, \tfrac{16}{18} = \text{Oxygen}.$$

---

* We use here approximate atomic weights instead of the exact weights.

Stated in the form of a proportion, this would be $18 : 2 : : 1 : \frac{2}{18} = \frac{1}{9}$. In this proportion, the fourth term must bear the same relation to the third that the second does to the first.

What is the percentage of calcium and oxygen in $CaCO_3$?

Since percentage means parts in 100, the first problem would be stated as follows:

$$CaCO_3 : Ca : : 100 : x$$
$$100 : 40 : : 100 : x = \frac{40}{100} = \text{or 40 per cent.}$$

In other words, calcium carbonate contains 40 per cent. of calcium. The same calculation may be made for oxygen, as follows:

$$CaCO_3 : O_3 : : 1 : x$$
$$100 : 48 : : 1 : x = \text{or 48 per cent.}$$

If, instead of percentage, we desire the amount in ten parts, we substitute ten for 100 in the third term of the equation, thus: $100 : 48 : : 10 : 4.8$ parts.

The fourth term of such an equation will always be of the same denomination as the third.

From the above we easily deduce the following rule for the statement of such problems: **As the formula of the substance given is to the formula of the substance required, so is the weight of the substance given to x, the weight of the substance required. Reduce the formulæ to their numerical equivalents, and find the value of x.**

When three terms of an equation are given, the fourth may be found by multiplying the two **means** (second and third terms) and dividing the product by the given **extreme**.

In calculating the percentage of any ingredient, by the above rule, the weight given is understood to be 100. Percentage is parts per hundred.

Calculations based upon a reaction may be illustrated as follows:

Problem.—How much sulphate of zinc can be prepared from ten grams of zinc?
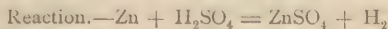
Reaction.—$Zn + H_2SO_4 = ZnSO_4 + H_2$
Statement.—$Zn : ZnSO_4 : : 10 : x$
Numerical statement.—$65 : (65 + 32 + 64 = 161) : : 10 : x$
Solution.—$161 \times 10 = 1610$
$1610 \div 65 = 24.8$, Ans. in grams.

Problem.—How much $NaNO_3$ will be required to make one pound of HNO_3?

Equation.—$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$.

The only terms of this equation concerned in the problem are $NaNO_3$ and HNO_3, the latter being the substance given.

Statement.—$HNO_3 : NaNO_3 : : 1 : x$ pounds.
Numerical statement.—$63 : 85 : : 1 : x$
Solution.—$1 \times 85 = 85$
$85 \div 63 = 1.35$ pounds of $NaNO_3$.

EXAMPLES FOR PRACTICE.

1. How much $FeSO_4$ can be made from one kilogram of iron?

2. How much mercury will be required to make one pound of calomel ($Hg_2 Cl_2$)?

3. Calculate the percentage of each element in the following: KBr, KI, $HgCl_2$, Fe_2Cl_6.

4. How much silver nitrate can be obtained from 100 grams of silver?

5. What is the volume of one kilogram of CO_2, under standard conditions?

6. Calculate the weight of one liter of chlorine.

7. How much bismuth will be necessary to prepare one kilogram of subnitrate?

8. Calculate the percentage composition of $C_6H_{12}O_6$.

9. What quantity of sodium carbonate will be required to neutralize five c.c. of a ten per cent. HCl?

$$2HCl + Na_2CO_3 = 2NaCl + H_2O + CO_2.$$
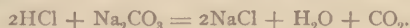
10. What weight and what volume of CO_2 will be given off in the above reaction?

11. Assuming that air contains twenty per cent. by volume of oxygen, what volume of air will be required to burn one gram of marsh-gas (CH_4)?

PART III.

INORGANIC CHEMISTRY.

Classification of the Elements.—For convenience of study, some system of classification of the elements is necessary. Many systems of classification have been proposed, but all are open to criticism; yet, we may adopt one of these with the understanding that the classification is largely an arbitrary one, and serves merely for convenience. Berzelius was the first to divide the elements into two great classes, to which he gave the names **metals** and **metalloids.** The metals are those elements which possess more or less luster and opacity, readily conduct heat and electricity, and are **electropositive** in combinations.

The non-metals, or metalloids, are such as are gaseous; or, if solid, have no luster, ductility, or malleability; are poor conductors of heat and electricity, and are **electronegative** in combinations.

This division, while it serves a general purpose, is not capable of exact application; for there are a number of the elements which are **positive** in one combination and **negative** in another. Iodine and arsenic, which most chemists regard as metalloids, have a decided luster, and the latter forms alloys by fusion with the metals; indeed, there is no line of demarcation between these two classes which can be regarded as fixed.

Some classification is necessary which is not based upon the physical properties alone, but upon their chemical properties; a classification which brings together those elements which have similar chemical properties and similar compounds with other elements, thus enabling the student to better associate the facts of each in his mind.

There are two important chemical characters upon which most attempts at classification of the elements into groups have been based —viz., valence and electrical polarity of the atoms. By a consideration of both of these properties, the elements may be grouped so as to bring similar elements together.

The behavior of the oxides of the elements with water may be taken as an index of their polarity. Electronegatives dissolve in water and form acids, while electropositives form bases, and some, again, play a neutral or double rôle.

The most successful attempt to find a natural system of classification of the elements is the one first proposed by Newlands and afterward developed by Mendelejeff, and is the only natural one in use. It is based upon the atomic weights, and is sometimes known as the **periodic law.** If a list of the elements be made, arranging them in the order of their atomic weights, from the lowest to the highest, the first seven (after hydrogen) will be found to be representative of seven groups of similar elements. (See table, p. 114.) Let each of these seven elements head a column, and arrange the rest under them in the order of their atomic weights, in lines from left to right. We notice that those elements resembling one another in their chemical properties will be found together in the vertical columns. It will be noticed that the metals are near the bottom of the table, while the non-metals are at the top. In Mendelejeff's original table there are seven vertical columns, which are called the seven groups. There are twelve lateral rows, which are called series, or small periods. If these lateral rows or series be numbered, it will be noticed that the members of the alternate numbered series of a given period resemble one another more nearly than the adjoining numbered ones. Thus, in the first group: $Li = 7$, $K = 39$, $Rb = 85$, $Cs = 133$, resemble one another more nearly than Na, Cu, Ag, Au. It will be noticed that hydrogen is arranged in the first period as the only one of that period. The table is imperfect in some cases, but in the main it brings together elements which form well-defined natural groups. As an example of such a group, take Nos. 2, 3, 5, and 7 of Group VII. With the increase of atomic weight they increase in specific gravity and consistency. Of the group, fluorine is strongly electronegative, while chlorine, bromine, and iodine grow less negative as the atomic weight increases. They all form acid hydrides containing one atom of basic hydrogen. They all possess a peculiar and somewhat similar pungent odor. They all have the leading valence of one, while the three last have a higher valence in certain oxygen compounds.

While there are certain striking groups brought together by this arrangement, there are some irregularities. Thus, there is no series in which hydrogen finds a place. In making this element a period by itself, the last four members of the second period, C, N, O, and F, are made even-numbered, which removes them from the others of the same group which they most nearly resemble. Even with these imperfections the table is an attempt to classify the elements upon some natural basis, and has enabled its author to predict the discovery of at least three new elements,—viz., gallium, scandium, and germanium,—and describe their properties, years before they were discovered. This he was led to do from the vacant places in the table.

10

Series.	Group I. $\overline{R_2O}$	Group II. $\overline{RO}$	Group III. $\overline{R_2O_3}$	Group IV. RH$_4$ $\overline{RO_2}$	Group V. RH$_3$ $\overline{R_2O_5}$	Group VI. RH$_2$ $\overline{RO_3}$	Group VII. RH $\overline{R_2O_7}$	Group VIII. $\overline{RO_4}$
1	H = 1							
2	Li = 7	Be = 9	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27	Si = 28	P = 31	S = 32	Cl = 35.5	A = 40 (?)
4	K = 39	Ca = 40	Sc = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63
5	(Cu = 63)	Zn = 65	Ga = 70	Ge = 72	As = 75	Se = 79	Br = 80	
6	Rb = 85	Sr = 87	Yt = 89	Zr = 90	Cb = 94	Mo = 96	= 100	Ru = 102, Rh = 104, Pd = 106, Ag = 108
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 120	Te = 125	I = 127	
8	Cs = 133	Ba = 137	La = 139	Ce = 140	Di = 142	Tb = 160		
9	(—)		E = 166					
10			Yb = 173		Ta = 182	W = 184		Os = 192, Ir = 193, Pt = 195, Au = 197
11	(Au = 197)	Hg = 200	Tl = 204	Pb = 207	Bi = 208			
12				Th = 232		U = 239		

Note.—The atomic weights given in the table are approximate values only.

As hydrogen stands alone in the table, we shall study it first. Argon and helium, the new elements found in the atmosphere, have not been studied sufficiently to admit of classification, and are therefore introduced provisionally in Group VIII. It will be convenient to retain the classification into **metals** and **non-metals**. The non-metals will be studied first, beginning with those of the seventh group, and taking the odd-numbered series below the second. The order in which the elements will be studied is the following, with the omission of those whose symbols are in italics, as being of little interest to the medical student :

NON-METALLIC ELEMENTS, OR ODD SERIES.

		H.	A.			
Seventh Group, ...	F.	Cl.	Br.	I.	
Sixth "	O.	S.	*Se.*	*Te.*	
Fifth "	N.	P.	As.	Sb.	Bi.
Fourth "	C.	Si.	*Ge.*	Sn.*	Pb.*

METALS.

First Group, ...	{ Li. Na. K. Rb. Cs.
	Cu. Ag. Au.
Second "	{ *Be.* Ca. Sr. Ba.
	Mg. Zn. Cd. Hg.
Third "	{ B.† *Sc. Yt. La. Yb.*
	Al. *Ga. In. E. Tl.*
Fourth "	*Ti. Zr. Ce. Th.*
Fifth "	*V. Nb. Di. Ta.*
Sixth "	Cr. Mo. W. *U.*
Seventh "	Mn.
Eighth "	Fe. Co. Ni. Ru. Rh. Pd. Os. Ir. Pt.

* These elements, although classed in the series with non-metals, are generally regarded as metals.

† Non-metal.

GROUP I.

HYDROGEN.

Symbol, H. Atomic Weight, 1. Molecular Weight, 2. Density, 1.
Weight of one liter = 1 crith = 0.0899 gram. Valence, I.

1 grain = 46.7 cu. in. at 60° F. and 30 in. barometer.
1 gram = 11.16 liters at 0° C. and 760 mm. barometric pressure.

Occurrence.—It was discovered in 1766 by Cavendish. Hydrogen occurs in a free state in the gases from volcanoes, fumeroles of Iceland and Tuscany, and in the atmosphere of the sun; in combination, it exists in water, and in most organic substances of both animal and vegetable origin.   It is a necessary constituent of all acids, bases, and ammoniacal compounds.

Preparation.—Hydrogen may be prepared:

First.—By the decomposition of water, by a strong electrical current, which splits the water into hydrogen and oxygen; the former appearing at the negative, and the latter at the positive electrode.

Second.—By decomposing water by certain metals. When sodium or potassium is used, the decomposition takes place in the cold; but with iron and some other metals, at a red heat.

$$Na_2 + 2H_2O = 2NaHO + H_2$$

$$3Fe_2 + 8H_2O = 2Fe_3O_4 + 8H_2$$
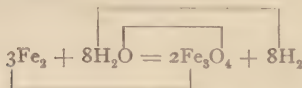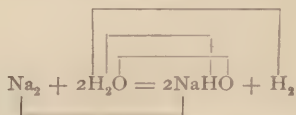
Third.—By the decomposition of the mineral acids with some metal, as zinc, iron, or magnesium. In this case, the metal takes the place of hydrogen, which is crowded out of the acid molecule.

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$
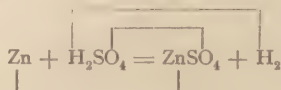
65 grams of zinc give 2 grams = 22.32 liters of hydrogen.

Water is added to dissolve the zinc sulphate formed, and to prevent it from crystallizing on the surface of the zinc. Chemically pure zinc, however, will not dissolve in very dilute acid, unless it be made one pole of a galvanic couple.

This method is the one usually employed for the preparation of hydrogen in the laboratory. The apparatus is shown in figure 44. The gas prepared from commercial zinc and acid is not pure, however, as it contains other gases derived from impurities in the materials used. Pure hydrogen in small quantities may be prepared by the first method, or by decomposing water with an alloy of sodium and mercury—sodium amalgam.

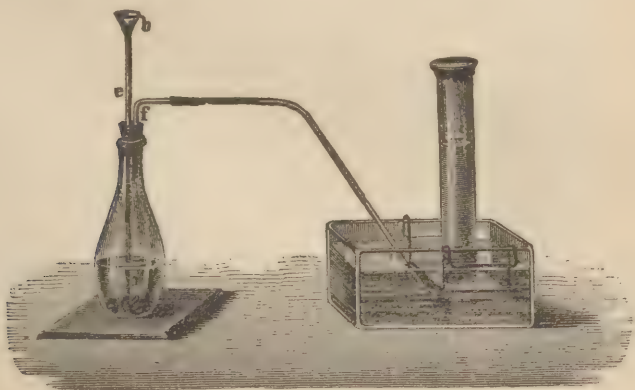**Properties.**—When pure, at ordinary temperatures and pressures,

FIG. 44.—PREPARATION OF HYDROGEN.

hydrogen is a colorless, transparent, odorless, tasteless gas. It is 14½ times lighter than air, being the lightest gas known.

One liter of it at 0° C. (—32° F.) and 760 mm. pressure, weighs 0.0899 gm. = the crith. It is almost insoluble in alcohol, and at a temperature of —240° C. (—408° F.), and under a pressure of 650 atmospheres, it has been condensed momentarily to a steel-blue liquid by the cold produced by its own expansion. Its boiling point has been stated to be —243° C. (—405.5° F.) and its critical temperature —233° C. (—387.5° F.). Hydrogen and helium are the only gases which have not been liquefied. It is the best conductor of electricity and heat among the gases. It is very diffusible, and a vessel to contain it must be made of glass or some very compact material. Certain metals absorb large quantities of it. Palladium will absorb 900 times its volume of the gas ; spongy plati-

num, sodium, potassium, and iron also absorb considerable quantities of it. This action of the metals is called **occlusion**. During the condensation of the gas in the pores of the metal, the latter expands and is heated to a considerable degree. A jet of hydrogen may be ignited by directing it upon a ball of finely divided platinum, or a ball of asbestos, which has been dipped into a solution of platinum chloride and heated in the flame of a lamp.

Under ordinary conditions, hydrogen has little tendency to unite with the other elements, chlorine being the only one with which it combines directly, and then only under the influence of light. At higher temperatures it unites with oxygen, and is, therefore, readily combustible in the air, burning with a bluish and very hot flame. The product of the combustion is watery vapor, as may be shown by inverting a jar over the burning jet and collecting the drops of water. A given weight of hydrogen produces more heat in burning than any other known combustible. It will not main-

FIG. 45.

tain animal respiration, but is not poisonous. A lighted candle is extinguished on being thrust into it, while the gas burns at the open mouth of the jar. On withdrawing the candle it relights. (See Fig. 45.) If hydrogen and oxygen be mixed together and a lighted taper applied to them, an explosion takes place. The hydrogen combines with one-half its volume of oxygen. In other words, when the gases combine they do so only in the one proportion. This law holds good with all chemical combinations, and is known as the **law of definite proportions**. Hydrogen has so great a tendency to unite with oxygen, at high temperatures, that it will take it from many metallic oxides, and leave the metal in the free state.

This process is called **reduction** or **deoxidation**. It is by this process that the **reduced iron** or **ferrum reductum** of pharmacy is produced.

Hydrogen will unite quite readily with some elements which it ordinarily does not affect, if they be put into the flask where the hydrogen is generating. Arsenic and antimony compounds, for example, are split up, and these elements unite with the hydrogen. Many oxides are reduced, and chlorine is removed from some chlorides, under these circumstances. The greater energy of the hydrogen, in these cases, is explained by the supposition that at the moment of liberation of the hydrogen atoms, and before they have combined into

molecules, they are ready to take up with any atom with which they may come in contact. They are stronger in their affinities, before combining with a neighboring hydrogen atom, by just the force it will take to decompose the hydrogen molecule when once formed. This condition of an element is known as the **nascent state** (from **nascere**, to be born). When any chemical action takes place between molecules, there is a considerable expenditure of force required to break up the combinations already formed, before new ones can be formed ; and when these combinations do not exist, the new combinations take place with ease. Hydrogen is one of the constituents of the gases of the stomach and intestines, and is frequently found in the gases exhaled from the lungs. Its physiological properties, if any, are slight.

In its chemical properties, hydrogen resembles the metals more than the metalloids, usually playing the positive rôle, and forming salts in which it occupies the place of metallic atoms in similar compounds. It is very probable that hydrogen forms an alloy with palladium, having the composition PdH_2. It is easily substituted for or displaced by them. On this ground, the acids may be regarded as salts of hydrogen.

Uses.—The uses of hydrogen are limited. Owing to its lightness, it is sometimes used to fill balloons. The ascensional power, or the lifting power, of one liter of hydrogen is 1.2033 gm., and is found by deducting its weight, 0.0899 gm., from the weight of one liter of air, 1.2932 gm. The lifting power of one cubic foot is about 525 grs., or one ounce and 55 grs. Hydrogen is also used with oxygen in the oxyhydrogen blowpipe. In the laboratory, it is used as a reducing agent.

ARGON.

$$A = 39.8 \ (?).$$

This element was discovered in the atmosphere in 1894 by Lord Rayleigh and Prof. Ramsay. The method of separation employed by them was to pass atmospheric air through a tube containing copper turnings heated to redness, to remove oxygen ; then through another tube containing magnesium heated to redness, to remove nitrogen. The residual gas was then passed over heated copper, copper oxide, and finally over heated magnesium again. This was repeated until the gas ceased to give up any more nitrogen to the magnesium, which usually required about two days. The amount of argon found in the air was a little less than one per cent. Whether this is constant in air at different places, can not be stated.

Properties.—Whether argon, as obtained by these experimenters, is an element, a modification of nitrogen, or a mixture of two or more

elements, has not been definitely settled. The evidence thus far tends to show that it is an element, and not a mixture.

The element is a colorless, transparent, odorless, tasteless, inert gas, having a density of 19.9. Its molecular weight is therefore 39.8.

At atmospheric pressure it liquefies at —186.9° C. (—304.5° F.) to a colorless liquid having a sp. gr. of 1.5. At about —190° C. (—311.3° F.) it freezes to an ice-like solid. It is soluble in water—to the extent of 4.05 volumes in 100 volumes—at 14° C. (57.2° F.), being two and a half times more soluble than nitrogen and of about the same solubility as oxygen. Of its chemical properties nothing can be said, as all attempts thus far have failed to cause it to combine with any other substance.

The molecule is monatomic, and therefore the atomic weight is 39.8.

$$\text{Density} \times 2 = \text{molecular weight.}$$

There are no compounds of argon known. Recently Ramsay and Travers have announced the discovery of two new elements in the atmosphere, which they name **krypton** and **neon.**

HELIUM.

$He = 4.36 \ (?).$

Helium is a gaseous element discovered by Ramsay in 1895 in the gases found occluded in certain minerals, especially in **cleveite** and **bröggerite.** Its spectrum is composed of a bright yellow line, coincident with the line D_3 of the solar spectrum. This line in the solar spectrum had been known for many years as the " helium " line, but did not correspond with any known terrestrial element. The gas is considered by some to be a mixture of two elements. It has resisted all attempts to liquefy it.

NON-METALLIC ELEMENTS OF GROUP VII.

(CHLORINE GROUP, OR HALOGENS.)

	SYMBOL.	ATOMIC WEIGHT.	STATE.
Fluorine,	**F.**	19	**gas.**
Chlorine,	**Cl.**	35.45	**gas.**
Bromine,	**Br.**	79.95	liquid.
Iodine,	**I.**	126.85	solid.

The elements of this group are electronegative, fluorine being most negative, and iodine least so. They have a characteristic, pungent odor, and act as disinfectants and bleaching agents. They enter into direct union with many of the metals to form binary compounds.

They form compounds with hydrogen, having well-marked acid properties. They have little affinity for oxygen, but form several oxacids and salts, all of which are rather unstable. They form the following compounds:

HF.	—	—	—	—	—	—	—
HCl.	Cl_2O	Cl_2O_3	Cl_2O_5	HClO	$HClO_2$	$HClO_3$	$HClO_4$.
HBr.	—	—	—	HBrO	—	$HBrO_3$	$HBrO_4$.
HI.	—	I_2O_3	I_2O_5	HIO	HIO_2	HIO_3	HIO_4.

FLUORINE.

(FLUORIN.)

$F = 19.$

Density, 19. Specific Gravity, 1.3. Valence, I.

Source.—The sources of fluorine compounds are native fluor spar (calcium fluoride) and cryolite—a sodium and aluminium fluoride.

Preparation.—By decomposing pure, dry hydrofluoric acid in a U-tube composed of platinum, by means of a strong electrical current from twenty or more Bunsen cells. The hydrofluoric acid must be prepared with care, and must be free from water. As hydrofluoric acid is a non-conductor, a small quantity of potassium hydrogen fluoride is dissolved in it to increase its conductivity. The apparatus is cooled to —23° C. (9.4° F.) during the process. The fluorine is liberated at the positive pole as a colorless, transparent, pungent gas, having the properties of chlorine, but much more marked. Silicon, boron, arsenic, antimony, sulphur, and iodine take fire in it. It instantly decomposes cold water, forming hydrogen fluoride, HF, and sets free the oxygen as ozone. Most organic bodies are attacked by it, the hydrogen being removed, but the carbon remaining unattacked. It combines with hydrogen with an explosion, even in the dark. Alcohol, ether, benzene, turpentine, and petroleum take fire on being brought in contact with it. It attacks the metals slowly, in bulk, but rapidly when in powder. Owing to the action of fluorine on the metals and all glass articles, it can only be prepared in vessels of platinum or fluor spar.

Hydrogen Fluoride, Hydrofluoric Acid.—HF. This acid is obtained by the action of sulphuric acid upon powdered fluor spar, with the aid of a gentle heat.

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

The operation is usually conducted in a lead or platinum vessel, as the acid attacks glass and most metals. The acid is a colorless, trans-

11

parent liquid, boiling at 19° C. (67° F.) and solidifying at —1.02° C. (30° F.). It fumes strongly in the air, giving off a pungent odor, very irritating to the skin and mucous membranes. It is readily soluble in water, forming a colorless, highly acid, and corrosive liquid with a pungent odor. Care must be taken in using it not to allow it to come in contact with the skin, as it produces a painful ulcer, which heals with difficulty, and also constitutional symptoms of considerable severity.

The sp. gr. of the liquid is 0.985 at 12° C. (53.6° F.). The most characteristic property of hydrofluoric acid is its power of dissolving glass by removing its silicon. This property is utilized for etching glass. The article to be etched is first coated with a thin layer of melted wax or paraffin, and the characters are then scratched through the wax with a steel point, so as to expose the glass where the etching is to take place. If the liquid is to be used, a wall of wax is built up around the characters and the liquid is poured into the inclosure. The characters thus etched are transparent. It is more common to invert the glass, wax downward, upon a leaden dish containing the fluor spar and sulphuric acid, and expose it to the fumes until the etching is as deep as desired. The etchings in this case are opaque, presenting the appearance of ground glass, and are more easily seen. Fluorine forms no oxides.
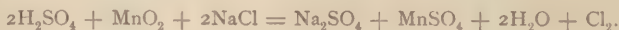
CHLORINE.

(CHLORIN.)

$$Cl = 35.5.$$

Density, 35.5.   Specific Gravity, 2.47.   Valence, I, III, V, or VII.

Occurrence.—Chlorine always occurs in combination in nature. The chlorides of sodium, potassium, magnesium, and calcium occur in salt springs. Usual source, sodium chloride, or common salt.

Preparation.—By the action of warm sulphuric acid upon sodium chloride, in the presence of manganic oxide, contained in a flask, as represented in figure 46.

$$2H_2SO_4 + MnO_2 + 2NaCl = Na_2SO_4 + MnSO_4 + 2H_2O + Cl_2.$$

Or, by acting upon manganic oxide with hydrochloric acid :

$$4HCl + MnO_2 = MnCl_2 + 2H_2O + Cl_2.$$

For a slow, continuous evolution of chlorine, for disinfecting purposes, moistened chloride of lime is exposed to the air. The calcium hypochlorite is decomposed by the carbon dioxide of the air, and

chlorine is set free.   For a more rapid evolution, we may use the same salt with a diluted acid.   It may be collected over warm water.

Physical Properties.—At ordinary temperatures chlorine is a greenish-yellow, pungent, suffocating gas.   It is irrespirable, causing, when breathed, inflammation of the air passages.   It is nearly two and a half times heavier than air; it is soluble in water, one volume of water dissolving nearly three volumes of the gas at 10° C. (50° F.). The solution (**aqua chlori,** U. S. P.; **liquor chlori,** Br. P.) is made at this temperature, and contains 0.4 per cent. by weight of the gas.   It is a greenish-yellow liquid, possessing the properties of the
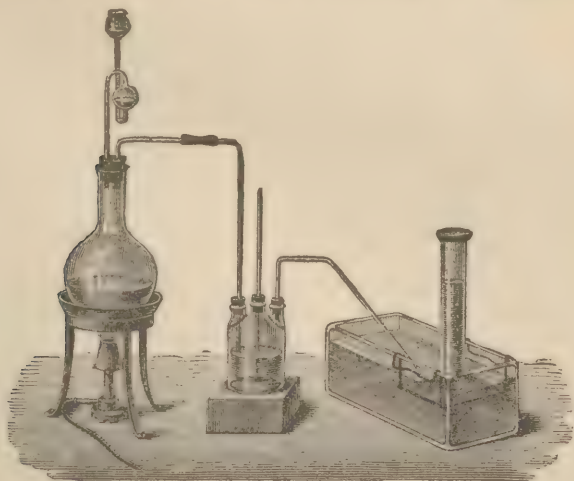
FIG. 46.

gas, but slowly changing, in the light, into hydrochloric acid.   It should bleach but not redden litmus paper.   Chlorine water should be kept in a dark place, as otherwise decomposition takes place.   The Cl unites with the H of the water, forming HCl, and setting O free. Under a pressure of eight atmospheres at ordinary temperatures, or a temperature of —34° C. (—29.2° F.), the gas is condensed to a bright golden-yellow liquid.

Liquid chlorine is now an article of commerce.   It is transported in lead-lined iron cylinders.   It is used in the extraction of gold from its ores.   It has a sp. gr. of 1.33 and boils at —33.6° C. (—29° F.).

Chemical Properties.—The affinities of chlorine are very strong and extensive. It is characterized by its strong tendency to combine with hydrogen and the metals, with which it forms chlorides. It combines directly with many elements,—as finely divided copper, antimony, or arsenic,—with the evolution of light and heat. Its attraction for hydrogen is so strong that when a mixture of these gases is exposed to direct sunlight, the light of burning magnesium, or the electric light, they combine, with an explosion. It burns rapidly in an atmosphere of hydrogen, forming gaseous hydrochloric acid, HCl. It is capable of existing in two **allotropic** states; the one active and the other passive. The passive or inactive form is the one obtained when the gas is prepared in the dark. When prepared in daylight it is very active in its properties. When an element is capable of existing in two or more forms, having different properties, these forms are called **allotropic** conditions; the property is called **allotropism.**

One of the most marked chemical properties of chlorine is its affinity for hydrogen. So great is this affinity, that many organic compounds are spontaneously decomposed by it; the chlorine combining with the hydrogen of the compound and setting the carbon free. A paper wet with turpentine and plunged into a jar of chlorine, takes fire and deposits the carbon as a dense black cloud, while fumes of HCl fill the jar. The well-known bleaching and disinfecting powers of chlorine are due to its affinity for hydrogen. Most vegetable colors, when moist, are readily discharged by chlorine. The chlorine combines with the hydrogen of the water and sets free the oxygen, which, in the nascent condition, is a powerful oxidizer, and decomposes the coloring agent or organized germ, as the case may be. In some cases the chlorine acts directly upon the organic matters, uniting with a portion of their hydrogen to form HCl, and a portion of it entering the molecule to take the place of the hydrogen removed. Thus, with marsh gas, hydrochloric acid and methyl chloride are produced. $CH_4 + Cl_2 = CH_3Cl + HCl.$

Hydrogen Chloride, Hydrochloric Acid, Acidum Muriaticum, Acidum Hydrochloricum (U. S. P., Br.).— HCl. Hydrochloric acid occurs very sparingly in nature. It is found in volcanic gases and in the gastric juice of mammals.

Preparation.—The acid is usually prepared from sodium chloride, or common salt, by treatment with commercial sulphuric acid, with the aid of a gentle heat.

The process is sometimes conducted in a special plant, but a large quantity of the acid is prepared, as a side product, in the manufacture of sodium carbonate by Leblanc's process. The first step in this process is to treat the salt with sulphuric acid, and thus convert it into

sodium sulphate. The acid set free by this process is collected and sold as impure hydrochloric acid.

$$H_2SO_4 + 2NaCl = 2HCl + Na_2SO_4.$$

Or—

$$H_2SO_4 + NaCl = HNaSO_4 + HNaSO_4.$$
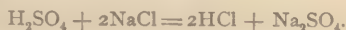
The acid may be prepared in small quantity by the direct union of equal volumes of chlorine and hydrogen, under the influence of sunlight or the electric spark.

Properties.—Hydrochloric acid is a colorless, transparent gas, having a pungent, penetrating odor, a sharp, sour taste, an acid reac-
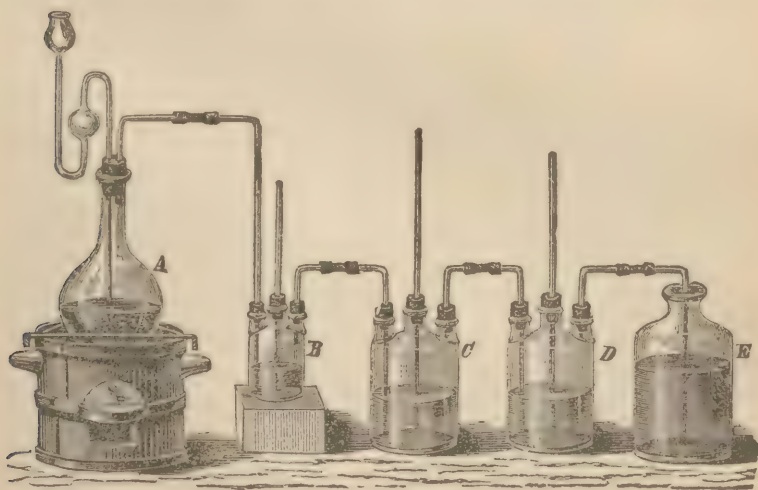

FIG. 47.—PREPARATION OF HCl.

tion, and producing great irritation of any tissue with which it comes in contact. It is irrespirable and extinguishes a flame. It is very soluble in water. One volume of this liquid dissolves 450 volumes of the gas at 15° C. (59° F.). This solution forms the ordinary **muriatic acid**. The sp. gr. of the solution is 1.21, and contains about 32 per cent. of HCl. The sp. gr. of the gas (air = 1) is 1.264; the density (hydrogen = 1) is 18.25. Under a pressure of 40 atmospheres, at 10° C. (50° F.), it condenses into a colorless, limpid liquid, having a sp. gr. of 1.27. A strong solution in water

fumes strongly in the air, giving off a part of the gas. On being heated it gives off its acid rapidly. The commercial muriatic acid is yellow in color, due to the presence of ferric chloride. It also contains other impurities, and is used only for manufacturing purposes.

The composition of the acid may be determined by means of the apparatus shown in figure 50, page 137. The apparatus is filled with the strongest commercial acid, mixed with ten volumes of a saturated solution of common salt, NaCl. The binding-posts are connected with a battery of two Bunsen cups. The chlorine separates at the positive pole, and the hydrogen at the negative pole. The volumes of the two gases are equal. By the use of the apparatus shown in figure 51, we may arrive at the same result by synthesis. We introduce, through the stopcock at the top of the apparatus, equal volumes of hydrogen and chlorine. By opening the stopcock below, we draw off the mercury until the height of the column is the same in both limbs. On passing a series of sparks from an induction coil (Fig. 34) through the mixed gases, they combine, with an explosion. No contraction is observed. No excess of either gas is left, but a new gas has taken their place—viz., hydrochloric acid. (See p. 88.)

Acidum hydrochloricum (U. S. P., Br.) is a colorless, fuming liquid, having a pungent odor and an intensely acid taste. Its sp. gr. is 1.163 at 15° C. (59° F.), and it contains 31.9 per cent. of absolute hydrochloric acid.

Acidum hydrochloricum dilutum (U. S. P., Br.) is made by diluting the stronger acid with water. (Strong acid, 100 parts; distilled water, 219 parts.) The sp. gr. is 1.050, and contains about ten per cent. of HCl. Pure hydrochloric acid should be colorless, and when diluted with distilled water should give no precipitate with H_2S, NH_4OH in excess, or $BaCl_2$, and should not dissolve gold leaf (absence of HNO_3).

Tests.—1. Heated with MnO_2, it gives off chlorine.

2. Added to $AgNO_3$. it gives a curdy, white ppt., soluble in ammonia water but insoluble in nitric acid.

$$AgNO_3 + HCl = AgCl + HNO_3.$$

3. Added to mercurous nitrate, it gives a white ppt., which is blackened by ammonia water.

$$Hg_2(NO_3)_2 + 2HCl = Hg_2Cl_2 + 2HNO_3.$$
$$Hg_2Cl_2 + 2NH_4OH = NH_2Hg_2Cl + NH_4Cl + 2H_2O.$$
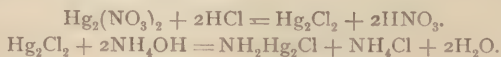
Nitromuriatic Acid, Acidum Nitrohydrochloricum (U. S. P.).—(Aqua regia.) This is made by mixing 180 c.c. of nitric acid with 820 c.c. of hydrochloric acid, in a capacious glass vessel, and when effervescence has ceased, pouring the product into amber-colored glass-stoppered bottles.

The two acids act chemically upon each other, forming chloronitric or chloronitrous gas and chlorine. The following equations express the reaction that probably occurs :

$$HNO_3 + 3HCl = NOCl_2 \, (?) + 2H_2O + Cl.$$
$$HNO_3 + 3HCl = \quad NOCl + 2H_2O + Cl_2.$$
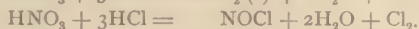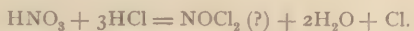
This acid has the power of dissolving gold, " the king of metals," and hence its name, aqua regia. It is a golden yellow, fuming, and very corrosive acid, smelling strongly of chlorine.

Acidum nitrohydrochloricum dilutum (U. S. P., Br.) is made by mixing 40 c.c. of nitric acid with 180 c.c. of hydrochloric acid, and when effervescence has ceased, adding 780 c.c. of distilled water.

BROMINE, BROMUM (U. S. P.).

(BROMIN.)

$$Br = 80 \, (79.34).$$

Specific Gravity, 2.99 at 15° C. (59° F.). Density of Vapor, 80.

History and Occurrence.—Discovered by Balard in sea-salt in 1826. It never occurs native, but is found combined with the alkaline metals and magnesium in sea-water, certain salt springs, and the ashes of seaweeds. The saline deposits of Stassfurt furnish a large part of the bromine of the market.

Preparation.—Sea-water or salt brine, which contains chlorides, bromides, and iodides of K, Na, Ca, and Mg, is evaporated down, so that some of the constituent salts are separated by crystallization.

The evaporation takes place first in large iron pans, and, after allowing the salts to settle, the liquor is further evaporated in a series of wooden tanks, five in number, which are heated by steam pipes ; these tanks are placed at different elevations, one above the other. The liquor remains one day in each tank, and when it reaches the lowest, or fifth tank, it contains only a few of the more soluble salts, chiefly bromide of magnesium. The crystals are removed from each tank before the liquor is drawn off.

The last mother liquor is called bittern. The bittern is treated with chlorine gas, which liberates bromine.

$$MgBr_2 + Cl_2 = MgCl_2 + Br_2.$$

It is then shaken up with ether, which dissolves the bromine and rises with it to the surface. This is separated with pipettes, mixed

with potassium hydroxide, and evaporated to dryness, leaving potassium bromide and bromate.

$$3Br_2 + 6KOH = 5KBr + KBrO_3 + 3H_2O.$$
$$5KBr + KBrO_3 + heat = 6KBr + 3O.$$
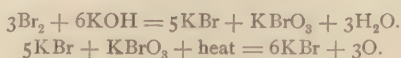
The potassium bromide is then treated with manganese dioxide and sulphuric acid, which liberates the bromine in a pure state.

$$2KBr + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + Br_2.$$

Properties.—Bromine is a heavy, dark red, mobile liquid, evolving, even at ordinary temperatures, a yellowish-red vapor, highly irritating to the eyes and lungs, and having a peculiar, pungent, suffocating odor, like that of chlorine.

It is soluble in thirty parts of water, readily soluble in alcohol, ether, carbon disulphide, and chloroform, imparting its color to the solutions.

It is completely volatilized on exposure to air. It destroys the color of litmus and indigo, and colors starch solution yellow.

Chemical Properties.—The chemical properties of bromine are similar to those of chlorine, but somewhat feebler. Bromine is poisonous. It may be recognized by its color, odor, or by the yellow or brown color of its solution in chloroform. It gives a yellow or orange color with starch paste. A solution of argentic nitrate precipitates it from its solutions, as a yellowish-white powder, which is soluble with difficulty in ammonium hydroxide.

Hydrogen Bromide, Hydrobromic Acid, Acidum Hydrobromicum Dilutum (U. S. P., Br.).—HBr. This acid may be prepared by treating phosphorus, immersed in cold water, with bromine, and distilling the resulting liquid. The bromine combines with the phosphorus, forming PBr_5, which is decomposed by the water into phosphoric and hydrobromic acids.

$$PBr_5 + 4H_2O = H_3PO_4 + 5HBr.$$
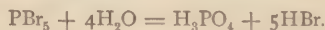
It may also be prepared by the action of dilute sulphuric acid (seven parts acid to one of water) upon a hot solution of potassium bromide. (Squibb.)

$$2KBr + H_2SO_4 = 2HBr + K_2SO_4.$$

Another method is to pass sulphuretted hydrogen through an aqueous solution of bromine.

$$Br_2 + H_2S = 2HBr + S.$$

Or by double decomposition between potassium bromide and tartaric acid.

$$KBr + H_2C_4H_4O_6 = HBr + KHC_4H_4O_6.$$

Bitartrate of potassium precipitates and leaves HBr in solution. The disadvantage of this method is that some of the bitartrate remains in solution. Diluted hydrobromic acid is official. It contains ten per cent. of absolute hydrobromic acid. It is a clear, colorless liquid, having properties closely resembling those of hydrochloric acid. Its sp. gr. is 1.077 at 15° C. (59° F.).

The acids and salts of bromine are analogous to the corresponding acids and salts of chlorine.

Hydrobromic is a monobasic acid, and forms compounds called bromides.

Tests for Bromides.—1. With silver nitrate a yellowish-white ppt. of silver bromide is produced, which is insoluble in nitric acid and sparingly soluble in ammonia water.

2. Treated with chlorine water, the bromine is liberated, and may be dissolved by shaking with chloroform, ether, or carbon disulphide.

IODINE, IODUM (U. S. P., Br.).

(IODIN.)

$$I = 126 \ (125.89) \ (H = 1).$$

Specific Gravity, 4.948.

History and Occurrence.—Iodine was discovered by Courtois in the ashes of seaweeds in 1812. It occurs in certain mineral springs with chlorine and bromine, but in less quantities. It is obtained mostly from the ashes of certain seaweeds collected on the shores of Scotland and France.

Preparation.—The seaweed is first dried in the sun, and then burned in shallow excavations, at a low temperature, so as not to volatilize the iodine. The ash (called "kelp") is then leached with water, which dissolves out the salts, and the solution is evaporated in open pans, so as to separate the other crystallizable salts. The mother liquid, called "iodine ley," which still contains some sodium carbonate, hyposulphite and sulphide, is mixed with one-eighth of its bulk of sulphuric acid and allowed to stand twenty-four hours.

Decomposition of the above-named salts takes place, with the evolution of CO_2, SO_2, and H_2S. The liquid, which contains iodine as sodium iodide, is then put into a retort, treated with manganese

dioxide and some more sulphuric acid, and heated.   The iodine distils over and is condensed in suitable condensers.

$$2NaI + 2H_2SO_4 + MnO_2 = Na_2SO_4 + MnSO_4 + 2H_2O + I_2.$$
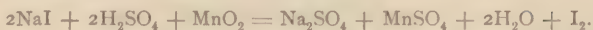
Iodine is a bluish-black crystalline solid, occurring in bright scales or tablets, which emit, even at ordinary temperatures, a very irritating, pungent vapor.   When heated, it melts at $114°$ C. $(237.2°$ F.), and is gradually dissipated in the form of a beautiful violet-colored vapor, of the density of 125.89.

Medical Uses.—It is used externally as a counter-irritant and discutient; internally as an antizymotic and alterative.   In large doses it acts as an irritant poison.   It is eliminated by the kidneys, saliva, and faucial mucous membrane, but not by the skin.   In administering it, silver spoons should be avoided, as it attacks silver.

The following three preparations of free iodine are official :

Tinctura iodi is a solution in alcohol (70 gm. to 1000 c.c.). When freshly made it is precipitated from this solution with water, but after some time it undergoes changes which prevent this.   The so-called **colorless tincture** is made by adding ammonium hydroxide to the above tincture, in sufficient quantity to decolorize it by converting the iodine into ammonium iodide.

Liquor iodi compositus (**Lugol's solution**) is a solution of iodine and potassium iodide in water.   Iodine, 5 gm. ; KI, 10 gm. ; distilled water, q. s. to make 100 gm.   **Unguentum iodi** contains four per cent. of iodine, rubbed up with potassium iodide and water and mixed with lard.

Hydric Iodide, or Hydriodic Acid.—HI.   A solution of this acid is prepared by passing hydric sulphide through water containing iodine in suspension, until the iodine disappears, and then filtering from the precipitated sulphur.

$$I_2 + H_2S = 2HI + S.$$

The acid, when pure, is a colorless gas, fuming in the air, having a penetrating odor resembling in most of its properties those of hydrochloric acid, although less stable and less active.   Solutions of hydriodic acid are very prone to decomposition, with liberation of free iodine.   **Syrupus acidi hydriodici** is official.   It is made by mixing an aqueous solution of potassium iodide with an alcoholic solution of tartaric acid.   The mixture is cooled by ice-water, the precipitate separated by filtering, and syrup added.   This syrup contains about 1 per cent. by weight of absolute hydriodic acid.

The reaction which takes place in the above process is thus expressed :

$$KI + H_2C_4H_4O_6 = KHC_4H_4O_6 + HI.$$
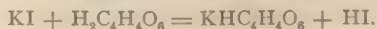
The iodides of potassium, sodium, iron, lead, mercury, arsenic, ammonium, and sulphur are used in medicine. The following compounds are also known: ICl, ICl_3, ICl_5, IBr, IFl_5, and NI_3. The last is a very explosive compound.

Tests for Iodine and Iodides.—1. Free iodine turns gelatinized starch blue.

2. To a solution containing free iodine add a few drops of carbon disulphide and shake. The carbon disulphide will fall to the bottom of the vessel in the form of a bead of a beautiful violet color. Chloroform may be used instead of the carbon disulphide.

3. To a solution of an iodide add a little chlorine water, and test for free iodine, as above.

4. To a solution of an iodide add nitrate of silver solution ; a pale yellow precipitate will form, which is insoluble in nitric acid and in ammonia water.

5. Acetate of lead gives a yellow precipitate of lead iodide.

GROUP VI.—NON-METALLIC ELEMENTS.

Oxygen, $O = 16$ (15.88) $(H = 1)$.
Sulphur, $S = 32$ (31.83) $(H = 1)$.
Selenium, $Se = 79$ (78.42) $(H = 1)$.
Tellurium, $Te = 126$ (126.52) $(H = 1)$.

The elements of this group are dyad, tetrad, or hexad, with the exception of oxygen, which is always dyad. They all combine with hydrogen in the proportion of RH_2. With the exception of H_2O their hydrides have acid properties. Oxygen is the most electronegative and tellurium the least so.
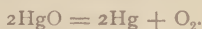
OXYGEN.

Symbol, O. Atomic Weight, 16 (15.88). Molecular Weight, 32. Weight of 1 liter, 1.43 gm. 16 gm. = 11.16 liters under standard temperature and pressure.

Occurrence.—Oxygen was discovered by Priestly, in England, in 1774, and at the same time by Scheele, in Sweden, independently of each other. It exists in the air, in the free or uncombined state, mixed with nitrogen and small quantities of other gases. It enters

into the composition of a great variety of compound bodies, such as minerals and vegetable and animal bodies. Water is eight-ninths, sand one-half, and alumina one-third oxygen, by weight.

Preparation.—Oxygen may be prepared :

First.—By heating mercuric oxide in a retort or flask, when it breaks up into oxygen and black mercurous oxide ; or, if the temperature be high, into oxygen and metallic mercury.

$$2HgO = 2Hg + O_2.$$

Second.—By heating black manganic oxide (MnO_2) to redness, in an iron or clay retort, when it gives off a part of its oxygen.

$$3MnO_2 = Mn_3O_4 + O_2.$$

Third.—By decomposing acidulated water with a current of electricity. The oxygen obtained in this way is very pure, but the method is too slow for ordinary use.

Fourth.—A good method, and the one most often employed, is by heating potassium chlorate.

$$2KClO_3 = 2KCl + 3O_2.$$

The evolution of the gas takes place more regularly, and at a lower temperature, if the chlorate be mixed with ferric oxide, cupric oxide, or manganic dioxide. In practice, the last is generally used, in the proportion of one part of the oxide to two or three parts by weight of the chlorate. The manner in which the oxide acts is somewhat obscure, for it seems to undergo no change in composition, and is found to be unaltered in the residue left in the retort.

The process may be conducted in a round-bottomed glass flask, furnished with a large-sized delivery tube, provided that the heat be carefully regulated and not allowed to become too high. The gas is collected in an inverted jar in a pneumatic trough. (See Fig. 48.)

One kilogram of the chlorate ought to yield about 140 liters, or five cu. ft., of oxygen.

Properties.—Oxygen, when pure, is, at ordinary temperatures, a colorless, transparent, odorless, tasteless gas, slightly heavier than air. Its sp. gr. is 1.10563. Water dissolves three per cent. of its volume, at ordinary temperatures. Under a pressure of 300 atmospheres, and at a temperature of —140° C. (—212° F.), it condenses to a transparent liquid, whose sp. gr. is 0.9787 (Pictet).

Liquid oxygen boils at —180° C. (—299° F.) under atmospheric pressure, and its absolute boiling point—above which it can not be condensed to a liquid, and known as the **critical temperature**—is

—113° C. (—203° F.). Every gas seems to have a critical temperature peculiar to itself. Oxygen is magnetic. The magnetism of the atmospheric oxygen is equal to that of a layer of iron covering the surface of the earth 0.1 mm. in thickness.

Oxygen forms oxides of all the known elements except bromine, fluorine, argon, and helium. Its range of affinities and its energy of combining power are its characteristic chemical properties. Most elements combine directly with it, especially at high temperatures. When this oxidation is accompanied by light and heat it is called **combustion**. A body is said to be combustible when it unites readily with oxygen, and emits light and heat in so doing. A combustible body usually requires to be heated to a more or less elevated
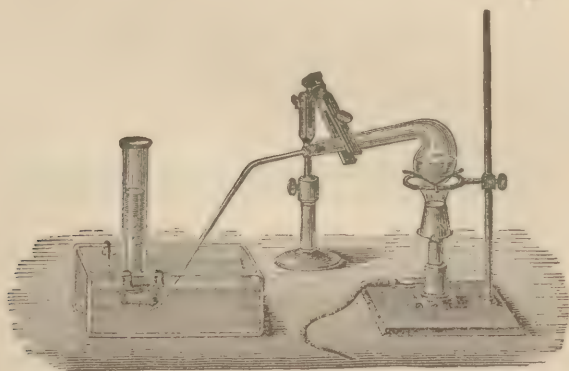
FIG. 48.

temperature before it will be acted upon by atmospheric oxygen ; but when the process has once begun, it is kept up by the heat generated in burning.

Some bodies, not usually regarded as combustible, will burn when heated to a red heat and plunged into an atmosphere of pure oxygen ; for example, a steel watchspring or small iron wire, so treated, will burn with great brilliancy. Bodies which burn in air with difficulty, burn in pure oxygen with great readiness. Oxygen is the great supporter of combustion, but the action of oxygen and the combustible body are mutual. A jet of air may be burned in a jar of illuminating gas or hydrogen as readily as these last burn in the air. Oxidation often takes place slowly, and the heat produced, although the same in both cases, passes off into the air or surrounding bodies, so that the

temperature does not rise much above that of the air. This is some-times termed **slow combustion**; or, more commonly, **oxidation**.

Most ordinary combustibles contain carbon and hydrogen, and in burning they produce carbon dioxide and watery vapor. In case the combustible contains sulphur, it becomes sulphurous oxide; if nitrogen, it becomes either free nitrogen or ammonia, according as the oxidation is complete or incomplete. The respiration of animals is similar in effect to combustion.

Uses.—The uses of oxygen are numerous. The oxygen taken into the air-vesicles of the lungs passes through their thin walls, by diffusion, into the blood. There it combines with the hemoglobin, and circulates with it throughout the body, assisting in burning up the waste products of the broken-down tissues. It is eliminated from the body as carbon dioxide and water.

One hundred volumes of arterial blood from a dog contain twenty-two volumes of oxygen (Gehaut), and this quantity varies with the amount of hemoglobin or with the red corpuscles of the blood.

FIG. 49.—COMPOUND BLOWPIPE.

Oxygen is used in the compound blowpipe, with hydrogen or illu-minating gas, to obtain a high temperature for working platinum or for the production of light. The gases are stored in separate recepta-cles under pressure, and are mixed in the blowpipe immediately before burning.
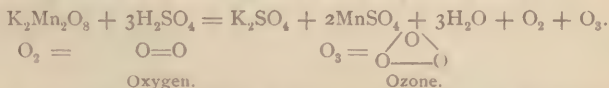
The construction of the blowpipe is shown in section by figure 49.

For the production of light, the flame is projected upon a small cylinder cut from unslaked lime. The flame heats the lime to a bril-liant white heat, which gives an intense light.

In the ordinary projecting lantern, the light from the heated lime is thrown through a lens upon a screen. Objects or transparencies placed in the light before the lens are then observed upon the screen. Oxygen, either pure or mixed with nitrogen or nitrous oxide, and condensed into cylinders, has been used with some success in the treatment of various lung affections. When taken in this way it acts as a tonic and stimulant, by oxidizing the blood; and, by forcibly inflating the lungs, it increases by several cubic inches the air capacity.

In the air, the oxygen is mixed with nitrogen to dilute it and to moderate its action. Oxygen is of use as a supporter of combustion, to afford us artificial heat and light. With this heat we drive our steam-engines, warm our houses, smelt our ores, and cook our food.

Ozone.—If a series of electric sparks be passed, for a few minutes, through a portion of air or oxygen gas confined in a tube, it acquires a peculiar pungent odor, exhibits properties which it did not previously possess, and undergoes a contraction in volume. The same odor is usually detected in the air in the neighborhood of a frictional electrical machine while in operation; or in the gas given off by a mixture of potassium permanganate and sulphuric acid;

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + O_2 + O_3.$$

$$O_2 = \quad O{=}O \qquad\qquad O_3 = \overset{O}{\underset{O{-}O}{\diagup\diagdown}}$$

Oxygen.   Ozone.

or when phosphorus, partially covered with water, is exposed to the air and allowed to undergo slow oxidation; or by the electrolysis of water containing sulphuric and chromic acids. Ozone can often be detected about a galvanic battery, using as the exciting fluid a solution of sulphuric acid and potassium dichromate.

Ozone has been prepared in the pure state by passing ozonized oxygen through a tube cooled by liquid oxygen to —184° C. (—299° F.). Thus prepared, it is a steel-blue liquid, boiling at —106° C. (—159° F.) and evaporating into a blue gas.

The density of the gas is 24, and its molecular weight is therefore 48, or $\overset{O}{\underset{O}{|}}{>}O$.

The ozone of the air never exceeds one part in 700,000. It is most abundant in May and June, and least in December and January. This property of an element assuming two or more forms of totally different behavior is called **allotropy** or **allotropism**. (See p. 124.) The more uncommon form of the element is called an allotropic form of the element. This property is exhibited by oxygen, sulphur, phosphorus, boron, iron, silicon, carbon, and perhaps others.

Properties.—The properties of ozone are those of oxygen, intensified. It is a very powerful oxidizing agent, tarnishes silver and mercury, sets iodine free from potassium iodide, and is rapidly destroyed by contact with easily oxidizable organic matters, and by a temperature of 149° C. (300° F.). In this last case, it is reconverted into oxygen. It is a strong bleaching agent. It is soluble in oil of turpentine and in ether.

In preparing ozone from oxygen a contraction takes place, and it

again expands on being reconverted into ordinary oxygen. This shows that it is a condensed form of oxygen.

Ozone is $1\frac{1}{2}$ times heavier than oxygen, and its molecule is represented by $\overset{O}{\underset{O\rule{0.6cm}{0.4pt}O}{\diagup\diagdown}}$ or O_3.

Tests.—The presence of ozone in the air may be detected by its action upon a paper saturated with a solution of potassium iodide and starch paste. This paper becomes blue by its action, owing to the liberation of iodine, which gives a blue color with starch. A piece of reddened litmus paper saturated with potassium iodide also becomes blue. A paper moistened with an alcoholic solution of guaiacum is also changed to a light blue by its action. A piece of paper impregnated with a solution of manganous sulphate or lead hydrate turns dark brown or black by its presence. These reactions disappear when the air is heated to 260° C. (500° F.). Ozone is found in the air, especially after thunder-storms, and when in appreciable quantities acts as a purifier of the air, destroying, by its oxidizing action, many forms of organized germs hurtful to animal and vegetable life. On this account it has been regarded as a valuable antiseptic and disinfectant. As it is very irritating to the mucous membranes, and when present to any considerable extent causes distressing coryza, or even hemoptysis, it is to be recommended with caution.

Hydrogen and Oxygen.—Two compounds of these elements are known :

Hydrogen oxide, or water, H_2O.

Hydrogen peroxide, or hydrogen dioxide, H_2O_2.

HYDROGEN OXIDE, OR WATER.

Formula, H_2O. Molecular Weight, 17.88 ($H = 1$).

Occurrence.—Water is so widely distributed in nature that it is almost universal. It exists in the three states : solid, liquid, and gas or vapor.

It occurs in the solid form below the temperature of 0° C. (32° F.), and as a liquid between 0° C. (32° F.) and 100° C. (212° F.), and as a vapor above 100° C. (212° F.). In the form of vapor it exists in the air at ordinary temperatures. It is poured into it from combustion in various manufacturing processes, from volcanoes, by spontaneous evaporation from the surface of the ground, bodies of water, and the leaves of plants. Seven-eighths of the entire human body is water. Potatoes contain 75 per cent.; watermelons, 94 per cent. ; and cucumbers, 97 per cent. It enters into the com-

position of many rocks, and forms a necessary part of many crystals, where it is known as water of crystallization.

Composition.—The composition of water may be determined in two ways : by analysis and by synthesis. If a current of electricity be conducted through a vessel of water, slightly acidulated with sulphuric acid, the water will be decomposed into two gases, hydrogen and oxygen, in the proportion of two volumes of the first to one of the second. If, now, these gases be mixed together in the same proportion, and an electric spark sent through the mixture, they
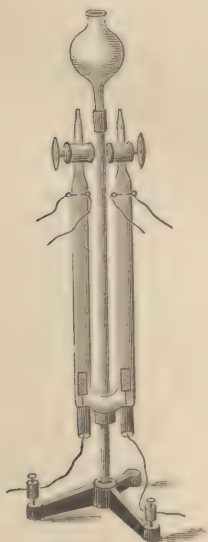
FIG. 50.
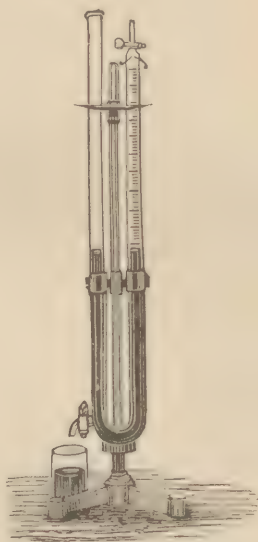
FIG. 51.

recombine, with an explosion. If **equal volumes** of the two gases be used, there will remain, after the explosion, one-fourth as much gas as was taken, which, on testing, will be found to be oxygen.

These two experiments show that the proportion of the gases, by volume, must be two of hydrogen to one of oxygen. On weighing the two gases, we find that the oxygen weighs eight times as much as the hydrogen—*i. e.*, by weight, water is composed of $\frac{8}{9}$ oxygen and $\frac{1}{9}$ hydrogen.

The recombination is effected in the eudiometer of the construction represented by figure 51, and the decomposition in the apparatus

12

shown in figure 50. For the synthesis of water, the mixed gases are introduced into the graduated limb (Fig. 51) through the stopcock at the top. The wires from a small induction coil are connected with the two platinum wires soldered into the glass just below the stopcock, and which are separated within the tube by a space about $\frac{1}{16}$ of an inch. On connecting the coil with the wires from the battery, a spark is sent across the space between the platinum wires, which ignites the gases. In figure 50 the wires are seen to pass through the tubes at the bottom and terminate in two strips of platinum foil, from which the gases escape to the top of their respective limbs. If the graduated limb in figure 51, containing the gases to be combined, be surrounded by a larger tube, through which steam from a kettle is kept passing, and the gases are measured at the same temperature, before and after the explosion, it will be found that the steam produced by the combination of the oxygen and hydrogen will occupy two-thirds of the volume of the mixed gases before the explosion (p. 88) ; that is, the two volumes of hydrogen and the one volume of oxygen have formed two volumes of steam, or vapor of water. Applying the law of Avogadro, it will be seen that there are the same number of molecules of water produced as there were molecules of hydrogen taken. Now, as we have seen (p. 88) that the hydrogen molecule contains two atoms, the molecule of water must contain two atoms of hydrogen. By the same reasoning it may be shown that the molecule contains but one atom of oxygen ; or, the formula is H_2O.

**Preparation.**—Water may be prepared in several ways by chemical means.

First.—The simplest method is the direct union of the gases.

$$2H_2 + O_2 = 2H_2O.$$
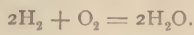
Second.—It is always produced by the burning in the air of hydrogen gas, or any combustible containing it, and may be condensed by conducting the products of the combustion through a tube or flue kept cool by immersion in cold water.

$$CH_4 + 2O_2 = CO_2 + 2H_2O.$$
Marsh   Oxygen.   Carbon   Water.
Gas.   Dioxide.
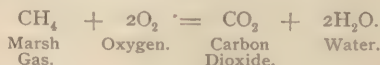
Third.—As one of the products of the action of an acid upon a base or a metallic oxide. Thus :

$$K—O—H + HNO_3 = KNO_3 + H_2O.$$
Potass.   Hydrogen   Potass.   Water.
Hydroxide.   Nitrate.   Nitrate.
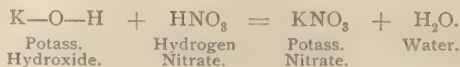
Fourth.—The reduction of a metallic oxide by hydrogen or some organic substance containing it.

$$C_2H_6O + 6CuO \text{ at red heat} = 3Cu_2 + 2CO_2 + 3H_2O$$
$$2CuO + 2H_2 = Cu_2 + 2H_2O.$$
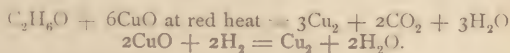
Physical Properties.—When pure, water is a colorless, transparent, mobile liquid, without taste or odor. When viewed in large quantity, however, it has a bluish color. It is a poor conductor of heat and electricity. When water is cooled below 0° C. (32° F.) it assumes the solid state, called ice. When the temperature is raised to 100° C. (212° F.) in ordinary conditions, it assumes the gaseous state, called steam. This point is called the boiling point. The boiling point is higher than 100° C. under an increased pressure. Solid matter in solution raises the boiling point and lowers the freezing point. Water at a temperature of 4° C. (39.2° F.) is taken as the unit of specific gravity of liquids and solids. At this temperature it possesses its greatest density. When it is heated above or cooled below this point, it expands and becomes less dense. Water is 773 times heavier than air at 0° C., and 11.147 times heavier than hydrogen. Water expands quite rapidly and with great force on solidifying, and hence ice is lighter than water. This expansion is supposed to be due to the greater space required for the molecules in arranging themselves into crystals. The form of the crystal of water is hexagonal. This may frequently be seen in small snowflakes received upon a dark surface; the lines of the three equal axes can often be seen with great distinctness.

The variations in the boiling point of water are much greater than those of the freezing point, but the latter is subject to slight variations of temperature. Water may be cooled in capillary tubes to —15° C. (5° F.) before it solidifies, if the tubes remain at rest; but if they are agitated when at this low temperature, the water will instantly solidify. The agitation favors the movement of the molecules into the position to form crystals, and hence large bodies of water freeze at a higher temperature when agitated by a gentle breeze than when the air is very calm. Although converted into vapor most rapidly at 100° C., water (even ice and snow) undergoes evaporation at all temperatures, especially when the air is dry. Owing to its great solvent power for solids, pure water is never met with in nature. There are comparatively few substances which are totally insoluble in water. When we wish to prepare pure water, we generally resort to the process of distillation, rejecting the first twenty per cent. of that which distils over, and also the last twenty per cent. It is by no means an easy matter to prepare absolutely pure water, even by this process;

but by conducting the process carefully, with the above precautions, we may obtain a water pure enough for all ordinary chemical purposes. Pure water is generally selected as the solvent of chemical substances which are to be submitted to any chemical change, because the reactions take place more readily in solution than when in the solid state, and because water is a neutral body, which does not complicate the result by taking part in the action itself.   The vapor of water is transparent, invisible, and colorless. Its density is 9, and its sp. gr., referred to air, is 0.6234.   One volume of water will produce 1696 volumes of steam, or, approximately, one cubic inch of water will produce one cubic foot of steam at 100° C. (212° F.), and one pound will absorb 536.0 units of heat, or 244 calories.

Chemical Properties.—We have already referred, in speaking of the preparation of water, to some of its chemical properties.   It unites directly with many metallic oxides to form bases or hydroxides, and with some oxides of the metalloids to form acids.

$$CaO + H_2O = CaO_2H_2 = \text{base.}$$
$$SO_3 + H_2O = H_2SO_4 = \text{acid.}$$
$$CO_2 + H_2O = H_2CO_3 = \text{acid.}$$
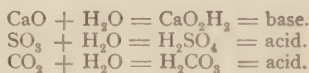
It enters into a feeble union with most metallic salts in solution, and separates with them when they crystallize, as water of crystallization. Certain substances, exhibit a marked tendency to combine with water, or to absorb it from the air, and are used in the laboratory as drying agents.   Among these are **calcium chloride, sulphuric acid**, and **phosphoric pentoxide.**

Natural Waters.—As already stated, natural waters are never free from dissolved impurities.   They contain gaseous, liquid, and solid impurities, varying according to the source whence these are derived, the temperature, the nature of the soil or rocks over which they have flowed, or the state of the air at the time.   Natural waters may be divided into **potable** (or drinkable), **mineral**, and **saline** waters.

Potable Waters.—To this class belong well-water, spring-water, river-water, lake-water, and ice-water.

The purest natural waters are **rain-** and **snow-water** from mountainous and country districts.   The purity of rain-water varies with the locality where it falls.   In the neighborhood of large cities, where the air is charged with the products of large factories, etc., it will contain whatever of these can be washed out of the air.

Sulphuric acid, for example, is comparatively abundant in the air of large cities.   The rain-water of London, as given by Dr. R. Angus Smith, contains 20.5 parts per million, while that of inland

places in England contains only 5.5 parts; and that from inland places in Scotland, only 2 parts, while from Glasgow it contained 70 parts per million.

The source of the sulphuric acid is mostly the combustion of coal containing sulphur. The chlorides in rain-water, principally **sodium chloride,** vary with the distance from the sea-coast.

Ammonium salts, nitrates, and nitrites are found in small quantities, derived from decomposing organic matter and from the combustion of coal. Another source of these compounds is the oxidation of a small quantity of the nitrogen of the air by ozone generated by lightning. Rain-water also contains more or less dust and organic matter, which it washes out of the air in falling. The gases found in rain-water are carbon dioxide, CO_2, nitrogen, oxygen, and sometimes, in cities, sulphur dioxide, SO_2, and hydrogen sulphide, H_2S.

Peligot's analyses show $\left\{ \begin{array}{ll} CO_2, & 2.4 \\ Oxygen, & 6.59 \\ Nitrogen, & 14.0 \end{array} \right\}$ c.c. per liter.

It will be noticed that the proportion of oxygen in the air of rain-water is about twice as great as that of the atmosphere.

Rain-water, as ordinarily collected on roofs of houses, is very much contaminated with both organic and mineral matter washed from the roof on which it falls. It is very liable to become putrid from the decomposition of this organic matter, and to breed the larvæ of certain insects. Melted snow furnishes a water even purer than rain-water, especially if we collect that which falls toward the end of a storm.

Ice-water varies very much in purity, according to the purity of the water from which the ice is obtained. Ice is always purer than the water from which it is formed, and when obtained from clear lakes or rivers it is often the purest of natural waters, owing to the fact that in the crystallization of water, or freezing, it leaves part of the dissolved solids and gases in the remaining water. The absence of the usual gases, however, renders ice-water **flat** to the taste.

Spring- and well-waters are simply rain-water which has been filtered through a more or less thick layer of soil. The nature and quantity of the dissolved matters will depend upon the nature of the soil and rock through which it percolates or over which it flows.

In large cities, where the soil is saturated with filth, the well-waters are very impure; while in well-drained and mountainous country districts they are much purer. Dangerous organic matter may filter through many feet of soil and poison the water of a well or spring.

Shallow wells usually contain much more organic and less mineral matter than deep wells, and are therefore more likely to contain dangerous or unwholesome matters. Shallow wells are essentially a pit for the reception and accumulation of the drainage from the surrounding soil. For convenience they are usually situated near the dwelling, where the soil receives more or less household waste of various kinds, and are often placed near a cesspool or privy-vault. The effect of the geological character of the soil is almost entirely obliterated by this local impurity. Such waters, even when disgustingly impure, are usually bright, sparkling, and palatable, and are often much approved by those accustomed to their use. Deep wells may be regarded as those which draw their supply from a depth of 100 feet or more from the surface. In cases where the supply is drawn from below a dense bed of clay or of impervious rock, the well may be considered deep when such supply is much less than 100 feet below the surface. Deep wells may be regarded as artificial springs, as both are subjected to the same conditions.

Artesian wells are artificial springs formed by boring into the earth, in a low-lying district surrounded by high ground, until a layer of rock or gravel containing water is reached, situated between two impermeable layers. The strata must be so curved that their outcrop is on a higher plane than the surface of the well. In such cases the water rises to the surface without pumping, and its character is determined by the nature of the rocks in which the water is found.

Surface Waters.—These comprise river-, pond-, lake-, and sea-water. The water-supply of large cities is usually taken from this class of waters, and consists of spring-water and of rain-water which has fallen upon a considerable area of country. Surface waters usually contain a large proportion of organic and mineral matters. Surface water, draining from a cultivated district, contains more organic and mineral matter than that from uncultivated districts, and the character of it is considerably influenced by application of fertilizers to the land. River-waters are often contaminated by the discharging of sewage and refuse into them from towns and various manufactories along their banks.

Characteristics of a Good Drinking-water.—(1) It should be clear and limpid. Cloudy and muddy waters should be avoided. (2) It should be colorless. A greenish or yellowish color is usually due to vegetable or animal matter in solution or to organisms. (3) It should be odorless; especially free from sulphuretted hydrogen or putrefactive animal matter. (4) It should not be too cold, but should have a temperature of from 8° C. (46° F.) to 15.5° C. (60° F.). (5) It should have an agreeable taste; neither flat, salty, nor sweetish. A certain

amount of hardness and dissolved gases give a sparkling taste. It should contain from 25 to 50 c.c. of gases per liter, of which 8 to 10 per cent. is carbon dioxide and the rest oxygen and nitrogen. The air of natural waters is richer in oxygen than the atmosphere above them—viz., about 33 per cent. of oxygen and 67 per cent. of nitrogen when the water is fully saturated, which is not always the case. Highly contaminated waters usually contain less oxygen than the above proportion, because it is used up in oxidizing the organic matter. (6) It should be as free as possible from dissolved organic matter, especially of animal origin. (7) It should not contain too great an amount of hardness. A certain quantity of saline matter is necessary, however, to give it a good taste. It should not contain over three or four parts of chlorine in 100,000 parts of water.

Sanitary Water Analysis.—We have seen that natural waters are never pure, but are contaminated by various kinds of foreign matter to which they have been exposed. These impurities may be harmless to the human economy, or they may be very harmful. It is the object of the analyst to determine, as nearly as possible, the nature and amount of impurities found in a water, so as to form an opinion as to its healthfulness.

It has been proven beyond doubt that water is a fruitful disseminator of disease. It is believed that the disease produced in such cases is due to microscopic organisms, and that the organic matter of the water simply furnishes a suitable solution in which they may live and grow. It is also known that these organisms grow best in solutions of organic animal matter, and this animal matter may be the carrier of the disease germs ; hence, waters contaminated with animal matters are looked upon as much more dangerous than those containing vegetable matter.

If the above idea be correct, it is evident that chemical analysis can not detect the disease-producing element, although it can tell **pure** from **impure** water.

Several methods are in use among chemists for the purpose of forming an opinion as to the character of drinking-waters. The elements usually relied upon in a sanitary examination are the total residue left on evaporation, the loss in weight of this residue on ignition at a dull red heat, the chlorides, the nitrates and nitrites, ammonia, organic carbon and nitrogen, and the quantity of oxygen the water will absorb from an acid solution of potassium permanganate. Poisonous metals should, of course, be looked for where there is any suspicion of their presence.

Total Residue.—The amount of residue left on evaporation serves, in a crude way, to indicate the amount of solids, but is only approxi-

mate, and of no significance unless it reaches more than 30 or 40 grains per gallon. This residue will, of course, vary with the hardness, or the amount of soluble constituents in the soil. By heating the solids to a dull red heat we expel all volatile and organic matter, including the water held by the calcium sulphate at the temperature of 100° C. (the temperature generally used in drying the residue), some carbon dioxide from carbonates, and oxides of nitrogen from nitrates and nitrites. The residue left after ignition gives a rough idea of the mineral matters present, and the loss on ignition should never reach 50 per cent. of the total residue.

Something may be gained by observing the color of the residue left on evaporation, which should be of a pure white color. It should blacken but very little on heating, and should give off no fumes. The residue of bad waters blackens very considerably, or gives off the odor of burning horn, or of nitrous fumes.

Chlorine in potable waters is very largely derived from the sodium and potassium chlorides of urine and sewage. The average amount of chlorine in urine is not far from 5 parts per 1000, or 500 parts in 100,000 parts of water. The average found in sewage is about 11.5 parts per 100,000. Over 5 parts of chlorine per 100,000 may be considered, in most cases, to be due to pollution of the water by sewage or animal excretions. This will be modified by the chlorine found in the purest waters of the same class, of that district. The source should always be taken into account in judging of the quality of a water. Proximity to the sea does not materially affect the amount of chlorine in well-waters. Too much dependence should not be placed upon the amount of chlorine in the water as a means of judging of its purity, for vegetable matter may exist in dangerous quantity without its presence being indicated by the chlorine present. Chlorine is estimated by a standard solution of argentic nitrate.

This solution is prepared by dissolving 4.8022 gm. of crystallized silver nitrate in a liter of water. Each cubic centimeter of this solution will precipitate 0.001 gm. of chlorine. One hundred c.c. of the water under examination is measured out into a beaker, just enough potassium chromate is added to give a distinct yellow tint, and then the above silver solution is run in from a graduated burette, a few drops at a time, until a slight red tint appears, showing that the chlorine has been precipitated, and that the silver is beginning to precipitate the chromic acid as red silver chromate. From the amount of silver solution used we may easily calculate the amount of chlorine present, for 1 c.c. of the silver solution precipitates 1 milligram of chlorine. The number of cubic centimeters of the silver solution used multiplied by 10 will give the milligrams of chlorine in 1 liter of water, or the parts per million. With many natural waters it is best to evaporate off about half the volume before titration.

Hardness.—The hardness of water is produced principally by the acid carbonates and sulphates of calcium and magnesium. The
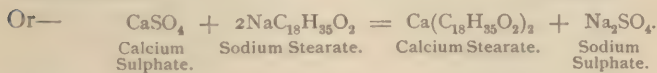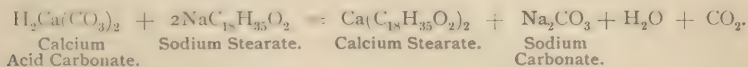
acid carbonates are decomposed by boiling, and the neutral salts precipitated :

$$CaH_2(CO_3)_2 = CaCO_3 + H_2O + CO_2.$$
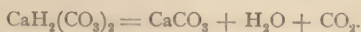
Hardness due to these salts is called "temporary," while that due to the sulphates of these metals is called "permanent hardness."

The hardness of water seems to have little or no influence upon the health of those who use it. Temporarily hard waters may be softened by adding lime in sufficient quantity to neutralize the excess of carbonic acid in the water, when the carbonate, $CaCO_3$ or $MgCO_3$, is formed, which settles to the bottom. The alkaline carbonates, Na_2CO_3 and K_2CO_3, may be used to precipitate permanent hardness and soften the water. Wood-ashes, which contain the latter of these salts, is frequently used by washerwomen to soften water for washing clothes.

Hardness is estimated by means of a standard solution of soap. Many samples of water possess both temporary and permanent hardness, and sometimes it is desirable to estimate them separately. For this purpose the total hardness is estimated in one sample, and the hardness in another sample is determined after boiling and separating the temporary hardness. The difference between the two determinations gives the temporary hardness. When soap is added to a hard water, the calcium and magnesium salts are precipitated according to the following equation :

$$H_2Ca(CO_3)_2 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2CO_3 + H_2O + CO_2.$$

<div style="padding-left:2em">Calcium   Sodium Stearate.   Calcium Stearate.   Sodium
Acid Carbonate.   Carbonate.</div>

Or— $$CaSO_4 + 2NaC_{18}H_{35}O_2 = Ca(C_{18}H_{35}O_2)_2 + Na_2SO_4.$$

<div style="padding-left:4em">Calcium   Sodium Stearate.   Calcium Stearate.   Sodium
Sulphate.   Sulphate.</div>

The calcium stearate in both cases is precipitated as a white, curdy-like mass. The hardness is estimated by taking advantage of these reactions. There is required for the estimation a standard solution of soap, made as follows : Ten gm. of shavings from a new cake of air-dried castile soap are dissolved in a liter of about sixty per cent. alcohol. Filter if not clear, and keep it in a tightly stoppered bottle. To determine the strength of the soap solution, dissolve exactly 1 gm. of pure $CaCO_3$ in a little HCl, neutralize with ammonium hydroxide, and add sufficient water to make 1 liter ; 1 c.c. of this solution will contain the equivalent of 0.001 gm. of calcium carbonate. Measure out 10 c.c. of this solution into an 8-ounce glass-stoppered bottle, add about 90 c.c. distilled water, and run in the soap solution, drop by drop, from a burette, shaking after each addition,

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until a lather is formed, which remains for five minutes. Note the number of cubic centimeters of soap solution used, and determine the amount of calcium carbonate precipitated by 1 c.c. of the soap solution as follows: Repeat the above experiment with 100 c.c. of pure distilled water. The amount of the soap solution required to produce a permanent lather in the distilled water must be deducted from the amount used in the above test. Usually it will not be far from $\frac{1}{2}$ to 1 c.c. The 10 c.c. of the solution of $CaCO_3$, used in the above-mentioned test, contained the equivalent of 10 milligrams of $CaCO_3$. Suppose, in the above-mentioned test, 8.5 c.c. of the soap solution were used to produce a permanent froth and 0.5 c.c. were required by the distilled water; then 8 c.c. were used to precipitate the 0.1 gm. of $CaCO_3$. Each cubic centimeter of this solution precipitated $\frac{1}{8}$ of 10, or 1.25 milligrams of $CaCO_3$.

The estimation of the hardness of a water is conducted exactly as the above process for standardizing the soap solution, except that 100 c.c. of the water under examination is placed in an 8-ounce bottle and the soap solution run in from a burette until a permanent lather is obtained. Multiply the number of cubic centimeters of soap solution added by the amount of $CaCO_3$, precipitated by 1 c.c., and this by 10, which will give the hardness reckoned as $CaCO_3$ in milligrams per liter, or parts per million. The hardness of waters varies so much that no average can be given. A water that does not contain more than 50 parts of hardness per million may be regarded as soft water, while one containing 150 is a hard water.

Nitrates and Nitrites.—These salts are usually looked upon as evidences of former contamination of a water by nitrogenous organic matter. The decomposition of organic matter of animal origin, in waters containing dissolved oxygen, yields nitrous and nitric acids, which combine with bases present to form salts of these acids. Rain-water contains a small quantity of these acids, but a larger quantity indicates that the water is undergoing, or has undergone, a natural process of purification from animal matters. This change is partially due to direct oxidation, but more particularly to the action of certain micro-organisms which have the peculiar power of converting nitrogenous organic matter into nitrites and nitrates, both in water and in soil. The process of disposing of nitrogenous organic matter or animal refuse, in natural waters, is to convert the nitrogen into ammonia, then into nitrous acid, and finally into nitric acid. The quantity of these compounds found usually indicates the amount of matter thus decomposed. This purifying process goes on more slowly in river- and lake-waters than in ground-water, because the exposure to oxygen is more complete while filtering through the soil than in

a body of water. Deep wells may safely contain more nitrates than shallow ones, for the organic matter may all be destroyed by filtering through the soil into a deep well, while in the shallow one some organic matter, germs, and spores capable of causing disease may pass undecomposed through the shorter distance. A careful estimation of nitrates gives, therefore, considerable knowledge of the past history of a water, and is regarded by chemists as of great importance.

A very easy and delicate test for nitrates and nitrites in water is the following: Make a solution of *diphenylamin* in pure, strong, sulphuric acid, free from nitric or nitrous acids, as shown by a duplicate test with distilled water, adding a little pure water to make a clear solution.

To the suspected water add one-half its volume of the sulphuric acid, then a few drops of the above solution. If nitrates or nitrites are present, a deep blue solution will be formed at once. This test may be used by any one, and will give some idea of the safety of a drinking-water.

To detect the presence of nitrites a solution of metaphenylendiamin in pure sulphuric acid may be used. When nitrites are present the solution assumes a yellow to brown color, according to the quantity present.

If to 100 c.c. of water we add 1 c.c. each of a saturated solution of naphthylamin chloride, sulphanilic acid, and diluted hydrochloric acid (1 to 3 of water), there appears, if nitrites are present, a pink color, the intensity of which is proportional to the quantity present.

A *quantitative estimation* of the nitrites requires the following reagents: (1) Sulphanilic acid, 1 gm., dissolved in 100 c.c. of hot water. (2) Naphthalamin hydrochlorate, 0.5 gm., dissolved in 100 c.c. of boiling water, kept in a glass-stoppered bottle, with a little pulverized carbon added to decolorize the solution. Filter or decant from the carbon when required for use. (3) Dissolve 0.275 gm. of dry silver nitrite in hot water, add a slight excess of sodium chloride, and dilute with pure water to 250 c.c. After the silver chloride has settled, remove 10 c.c. of the clear solution and dilute with water to 100 c.c. One c.c. of this solution, which is used in the analysis, is equivalent to 0.01 milligram of nitrogen.

The Process.—One hundred c.c. of the water are placed in a cylinder, previously cleansed, and 2 drops of strong hydrochloric acid added. One c.c. of the sulphanilic acid solution, followed by 1 c.c. of the solution of naphthalamin hydrochlorate are added, mixed, and covered to exclude dust, and let stand for thirty minutes. One c.c. of the standard nitrite solution (No. 3) is placed in another glass cylinder, water free from nitrites is added to make 100 c.c., and the whole treated with the same reagents as the above. At the end of a half-hour the two solutions are compared. The colors are brought to the same tint by diluting the darker, and the calculation made as to the amount of nitrogen, as nitrite, in the 100 c.c. Suppose, for example, the 100 c.c. of the water require dilution to 125 c.c. in order to make this tint agree with that produced by 1 c.c. of the standard sodium nitrite solution, which contains 0.01 milligram of nitrogen as nitrite; then $100 : 125 : : 0.01 : x = 0.0125$. That is, the water contains in 100 c.c., 0.0125 milligram of nitrogen in the form of nitrites, or 0.125 milligram per liter, or 0.125 part per million. Leeds places the limit for American rivers at 0.03 per 100,000, and Mallet places the average in good waters at about 0.014 part per million. When the quantity exceeds 0.02 in 100,000 it is considered as indicating previous contamination by organic matter whose nitrogen has been converted into nitrous acid.

The nitrates are estimated by acidulating 500 c.c. of the water with oxalic acid,

pouring half of it into each of two wide-mouthed bottles.   Into one of these is put a copper zinc couple, made by taking a piece of sheet-zinc (4 by 6 in.), rolling it into a loose coil, and immersing it in a 1.5 per cent. solution of copper sulphate until the surface is covered with an even layer of copper.* Cork both bottles and let them stand for twenty-four hours. Remove 50 c.c. from each bottle and Nesslerize as di rected under Ammonia.   The difference between the two readings gives the ammonia due to the reduction of the nitrites and nitrates present.   The nitrogen in the pre viously determined nitrites must be subtracted, when the remaining nitrogen will be that from the nitrates.   If the nitrogen, as nitrates, exceeds six parts per million, the water is suspected of having been polluted.

Moist Combustion or Oxygen-consuming Power.—By this is meant the oxidation of the organic matter found in a water, by adding to it a measured quantity of potassium permanganate, with some sulphuric acid, and determining the oxygen absorbed from this salt by the organic matter present.   This method can not distinguish between vegetable and animal matters ; neither will it measure the oxygen consumed in oxidizing nitrites to nitrates, or ferrous to ferric salts.   In the presence of these salts it may give erroneous results. Most chemists regard the process as of some value in giving an idea of probable pollution by organic matter, as it has been shown that dangerous organic matter is more easily oxidized than that which is harmless.

The **quantitative process** requires the three following solutions : (1) **Potassium permanganate solution.**   It is conveniently made of such strength that 1 c.c. will yield 0.1 milligram of oxygen for oxidation.   Such a solution will contain 0.3952 gm. of the salt in 1 liter of distilled water.   (2) **Solution of oxalic acid.**   Dissolve 0.7875 gm. crystallized oxalic acid in 1 liter of water.   One c.c. of this solution, when titrated with the potassium permanganate solution, in the presence of sulphuric acid and while hot, should just decolorize 1 c.c. of permanganate solution.   (3) **Dilute sulphuric acid, 1** part strong acid to 3 of water.   Add enough permanganate solution to give a faint pink tint after standing four hours.

Method of Procedure.—Measure 200 c.c. of the water under examination into a half-liter flask, add 10 c.c. of the diluted sulphuric acid, and enough of the potas sium permanganate solution from the burette to give it a marked red color.   Boil for ten minutes, adding more of the permanganate solution from time to time, if neces sary, to maintain a red color of about the same intensity.   Remove the lamp, add 10 c.c. of the oxalic acid solution to destroy the color, and then add more of the potassium permanganate from the burette until a faint pink tinge again appears. From the total amount of permanganate used deduct the 10 c c. which were used up by the oxalic acid solution.   The remainder will give the amount of permanganate used by the water, or the number of milligrams of oxygen actually absorbed by the water. This quantity multiplied by 5 will give the number of milligrams of oxygen absorbed by a liter of water under the above conditions, or the parts per million.   Waters ab sorbing more than 2 parts of oxygen in 1 million should be considered as of doubtful purity.   Those absorbing 5 parts should be regarded as organically impure.   Leeds gives as a limit for American rivers from 5 to 7 parts per million.

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* Sodium amalgam has been recommended instead of the zinc-copper couple for reducing the nitrates and nitrites.

Another process allows the mixture of the water, acid, and permanganate to remain at the room temperature for a longer time.

Five stoppered bottles, each holding 500 c.c. (a pint), are thoroughly cleansed with pure sulphuric acid. To each add 250 c.c. of the water to be tested, and 10 c.c. of the sulphuric acid. Then add varying amounts of the permanganate solution, say 2, 4, 6, 8, and 10 c.c. respectively. They should be inspected at the end of one, two, three, four, and twelve hours, and the effect noted. If all the solutions should be decolorized before the end of the fourth hour, 10 c.c. are added to each, and the result again watched. In fairly good waters not more than the first two or three will decolorize in four hours; that is, 250 c.c. of water should not absorb more than 1.5 to 2 milligrams of oxygen.

This process is simple, and requires little skill when the solutions are once prepared.

Ammonia.—The spontaneous decomposition of organic matter in water first affords ammonia, then nitrites, and finally nitrates. This fact is so generally conceded as to make an estimation of the ammonia in a water a very important part of its sanitary examination.

The ammonia is generally spoken of as **free ammonia**, or more properly **ammonium salts**; and **albuminoid ammonia**, or **ammonia from organic nitrogen**. The sanitary examination of a water should always include a quantitative estimation of the ammonia and organic nitrogen.

The method usually adopted for this purpose is that known as the Wanklyn process, and is the one which yields the best results.

The process requires several solutions and considerable care in manipulation in order that the results may be reliable. The solutions required are: (1) **Nessler's solution.** Dissolve about 35 gm. of potassium iodide in 100 c.c. of water, and 17 gm. mercuric chloride in 300 c.c. of water. When solution is complete, add the latter solution to the former until a permanent precipitate is produced. Then dilute with a twenty per cent. solution of sodium hydroxide to 1 liter. Now add the mercuric chloride solution again until a permanent precipitate forms. Let settle till clear, decant, and use the clear solution. It improves on keeping, and will detect extremely minute quantities of ammonia. (2) **Sodium carbonate.** A saturated solution of pure, freshly ignited sodium carbonate in water free from ammonia. (3) **Standard ammonium chloride solution.** Dissolve 0.314 gm. of ammonium chloride in 100 c.c. of water; 1 c.c. of this solution is then diluted with 99 c.c. of ammonia-free water. This last solution will contain 0.00001 gm. of ammonia in each cubic centimeter, and is the solution employed in the analysis. (4) **Alkaline potassium permanganate.** Dissolve 8 gm. of pure potassium permanganate crystals and 200 gm. of potassium hydroxide in water, and make up to a liter. The solution is put into a flask or retort and distilled. The distillates are collected and tested with the Nessler solution until they cease to give a reaction for ammonia, when the solution is ready for use. (5) **Water free from ammonia.** A good clear well- or hydrant-water is treated with a few cubic centimeters of the sodium carbonate solution, and distilled until a small portion of the distillate shows no reaction with Nessler's test. The remainder, except the last portion, will usually be found to be absolutely free from ammonia. Or, we may add to the water a few drops of strong sulphuric acid and distil, rejecting the first one-tenth of the whole volume, when the remainder will usually be found to be free from ammonia.

The Process.—One hundred c.c. of pure distilled water are put into a retort hold-ing about half a liter. To this is added 2 c.c. of the sodium carbonate solution. The retort is connected with a Liebig condenser by an air-tight joint made by a piece of black rubber tubing of large caliber drawn over both the retort and condenser. The beak of the retort is bent at such an angle that the lower end may be attached to the block-tin tube of the condenser, as shown by figure 52. A lamp is now brought under the retort and the water rapidly boiled until 10 c.c. of it shows no reaction with Nessler's reagent. One hundred c.c. of the water under examination are now put into the retort by means of a funnel, and the boiling continued slowly, removing the distillate when 10 c.c. are collected. Four distillates of 10 c.c. each usually con-
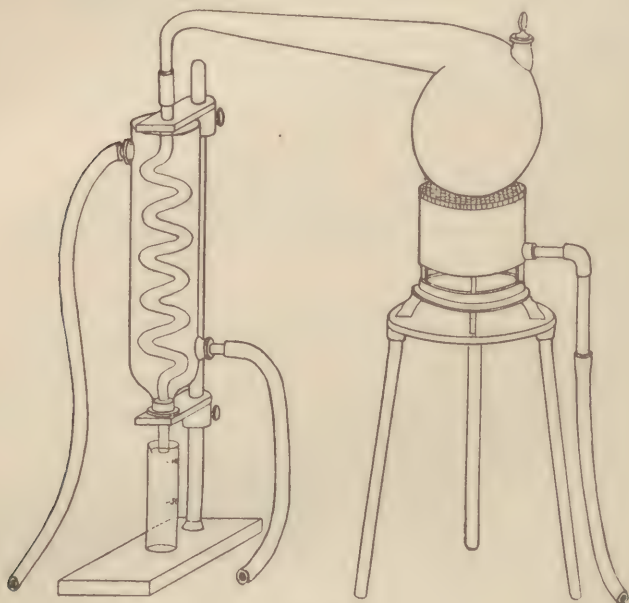
FIG. 52.

tain all the ammonia existing in the water as salts of ammonia. Many prefer to use 500 c.c. of the water instead of 100 c.c. and distil off 50 c.c. of the solution for Nesslerizing. The author prefers the smaller quantities, using smaller tubes graduated at 10 c.c. The process of Nesslerizing is conducted as follows : 0.5 c.c. of the Nessler solution is measured into each of the four distillates and mixed by agitation. The weaker ammonia solution is now added to 10 c.c. of the ammonia-free water in another cylinder, until the color produced with 0.5 c.c. of Nessler's solution is equal to that in the first distillate removed. Each distillate is imitated by a known amount of ammonia in the same volume of liquid. Some chemists recom-mend to add one-third of that found in the first distillate as an average amount to be

found in the remaining ones. When about 40 c.c. have distilled over, the lamp is removed and 10 c.c. of the alkaline permanganate solution is added to the retort and the distillation slowly continued, setting aside each distillate when 10 c.c. are collected. These distillates are again Nesslerized, as in the case of the first distillate. The color of each cylinder is imitated in other cylinders with a known amount of ammonia, and the amounts so obtained are added together to obtain the total amount of ammonia. After a little practice it will be easy to imitate the color of any distillate by this process. It is necessary to note not only the absolute quantity of albuminoid ammonia, but the rapidity with which it is set free and distilled over. If it comes very rapidly, it indicates that the organic matter is in a putrescent or decomposing condition. If, on the other hand, the ammonia distils gradually, it indicates the presence of organic matter in a comparatively stable or fresh condition. It is best, therefore, to keep the record of each distillation, so that the rapidity with which the ammonia is set free, as well as the actual amount, may be known. If a water yields no albuminoid ammonia, it is free from recently added organic contamination. Usually, however, it gives a very small amount. If it contains more than 0.1 milligram per liter, the water is looked upon as supicious, and is to be condemned when it reaches 0.15 milligram per liter, or 0.15 part per million. If free ammonia is present in a considerable quantity, then the albuminoid ammonia is indicative of contamination when it reaches over 0.05 milligram per liter. An opinion should not be formulated, however, without a knowledge of the source of the water examined. Free ammonia may exist in larger quantities in some deep wells without indicating dangerous contamination.

Biological Examination of Water.—In recent years it has been customary to determine the nature and number of the micro-organisms in water by the well-known bacteriological methods.

Surface-waters and many well-waters contain a variety of living organisms which may be easily discovered by the aid of a microscope ; such as the **daphinæ, cyclops, desmids, algæ, rotiferæ, amebæ,** etc. These organisms feed mostly on suspended organic matter, and are not regarded as especially harmful, except in the case of some of the entozoa. Dissolved organic matter in a state of decomposition is generally indicated by bacteria.

The principal object in view, in these examinations, is to determine the number of organisms in a given volume (1 c.c.) of the water, and, if possible, to determine the character of these organisms. The cultivation of the organisms requires care and skill, and even then the value of the results is open to great question. Pathogenic bacteria have rarely been found by this method, and the chemical methods are still relied upon. While much is to be hoped for in the future, the process has not thus far given results which, taken alone, can replace the older chemical methods above referred to. Every sanitary analysis should comprise both methods of examination, and should also include an inspection of the source of the water.

We have thus briefly outlined the methods in use for testing drink-

ing-waters, for the purpose of giving the student some knowledge of the subject, without going into tedious details, which are intended only for the chemist, and which do not come within the scope of this work.

Purification of Water.—Water may be separated from suspended impurities by filtration—*i. e.*, by passing it through any porous substance not soluble in water, as clay, sand, charcoal, brick, unglazed earthenware, unsized paper, etc. For filtering large quantities of water for cities or manufactories, sand or brick is to be preferred. For filtering water for family use, a brick partition two to four inches thick, built from wall to wall in a cistern, works well. The water is delivered in one apartment and pumped from the other for use. Or a barrel, in the bottom of which several holes are bored, may be filled with alternate layers of gravel, sand, and charcoal, and placed over the mouth of the cistern or reservoir, through which the water may be filtered. Such a filter, when freshly made, will remove a part of the dissolved organic matters as well as suspended matters. Porous stone filters, made from a silicious stone, are to be found in the market, which filter rapidly and very satisfactorily. Spongy iron filters, made by roasting hematite with coal, are still more active in destroying organic matter and putrefactive germs. But few of the various forms of commercial filters remove micro-organisms from water ; on the contrary, many of them, after being used for a short time, begin to contaminate the water with microscopic organisms which they harbor in their pores. Filters of unglazed porcelain are now in the market, which will remove micro-organisms from solutions. Sand filters are most efficient for filtering large quantities of water for the supply of cities. Experiments have shown that a sand filter five feet in depth, when the water passes through it at the rate of 2,000,000 gallons per acre a day, will remove 99.98 per cent. of the bacteria contained in the water. It has been shown that polluted waters are rendered almost harmless by such filtration. Typhoid fever and cholera germs are almost completely removed by such filters.

In some cities a process of ''scouring,'' or agitation of the water with angular sand, is practised. In others there is employed a combination of a precipitant of the organic matter and filtration. The precipitants are either alum or a ferric salt. The Hyatt and National systems operate on this principle, and are said to be efficient, where the amount of water to be treated is not too great. In the Anderson system the water is agitated with iron borings, in a revolving iron cylinder, which forms a certain amount of ferrous carbonate from the carbonic acid of the water. The temporary hardness is thus largely removed by the removal of the carbonic acid. On ex-

posure to air the ferrous carbonate is oxidized and ferric hydroxide is precipitated.

$$2FeCO_3 + O + 3H_2O = Fe_2(OH)_6 + 2CO_2.$$
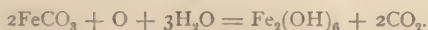
The water is then filtered through sand. The organic matter is largely removed by this process, as is shown by analysis, and the organisms as well. The time of contact of the water and iron is about three or four minutes. This process has been tried in some large cities, and is highly spoken of.

Organic matter may be largely removed from water by precipitation with alum or ferric chloride. When alum is added to a water, it is decomposed, with the formation of the hydroxide which, as it settles, carries down with it all suspended matters and a large part of the dissolved organic matter and micro-organisms. From one to two grains to the gallon is sufficient. Ferric salts behave in a similar manner. Filtration through granulated iron, kept clean by agitation, and afterward filtering through sand, serves to remove a large part of the organic matter and microbes.

We have already referred to methods of precipitating the **hardness** from water. Distillation, as a means of purifying water, has also been referred to. Freezing purifies water, and removes, to a considerable extent, mineral as well as organic matter ; but freezing can not make a dangerous water safe. Numerous instances show that disease may be communicated as surely by ice as by unfrozen water.

Mineral Waters.—Under this name are included such waters as, from some dissolved substances, have a greater or less therapeutic value. These vary so much in the character of the dissolved substances that no exact classification of them can be made, but they may be roughly classified as follows :

1st. **Carbonated waters,** those which are charged with carbon dioxide or carbonic acid.

2d. **Sulphuretted waters,** those which contain sulphides of hydrogen or one of the alkaline metals, in notable quantities. They are used for baths as well as for drinking.

3d. **Alkaline waters,** those containing considerable quantities of carbonates or bicarbonates of the alkaline metals—sodium, potassium, or lithium.

4th. **Saline waters,** those containing the neutral salts, such as the chlorides, bromides, or iodides of the alkalies or alkaline earths.

5th. **Chalybeate waters,** those containing some one of the compounds of iron. Closely allied with these in properties are those containing manganese.

6th. **Acid waters,** those containing free mineral acids, such as hydrochloric or sulphuric acid.

7th. **Thermal waters,** or such as come to the surface at a temperature above that of 20° C. (68° F.). Some of these springs contain so little mineral matter as to be of no importance; the only value, if any, being in the temperature. They are used principally for baths.

Official Forms.—Aqua. Natural water in the purest attainable state (U. S. P.). Natural water, the purest that can be obtained, cleared, if necessary, by filtration (Br.). **Aqua destillata.** Take of water 1000 vols.; distil 100 vols., reject, then distil 800 vols. (U. S. P.) The transparency or color of distilled water should not be affected by lime-water; nor by H_2S, $BaCl_2$, $AgNO_3$, or $(NH_4)_2\cdot C_2O_4$, etc.

The **aquæ** of the U. S. P., or **medicated waters,** are solutions of a gaseous or volatile body in water, as **aqua ammoniæ, aqua chlori.** A **liquor** is a solution of a fixed or solid body, as **liquor ferri nitratis ; liquor plumbi subacetatis.** A decoction is a solution made with boiling water, usually of a vegetable product. An **infusion** is a solution formed by subjecting the body for a short time to either cold or warm water. **Maceration** is the long-continued action of water at the ordinary temperature. **Digestion** is the same with hot but not boiling water. **Lixiviation** or **leaching** is the process of pouring water through a porous mass of any substance, for the purpose of dissolving out soluble matters.

Physiological Use.—Water exists in all the tissues of the body and in all foods and drinks. A healthy adult takes, on an average, about 2.5 liters of water in twenty-four hours; and loses by the skin, lungs, kidneys, and feces a little more than this; the **excess** coming from the oxidation of the hydrogen of the food and tissues. Water constitutes from sixty-five to seventy per cent. of the whole body, being in slightly larger proportion in the young than in the adult body. The water in the tissues serves as a solvent for the various proximate principles intended as nourishment for the tissues, or coming from their waste and intended for excretion. The evaporation from the skin serves to carry off the superfluous heat of the body.

Hydrogen Dioxide, Hydrogen Peroxide, H_2O_2, **Aqua Hydrogenii Dioxidi** (U. S. P.).—The simplest way of preparing a diluted solution of H_2O_2 is to pass a stream of CO_2 through water containing barium peroxide, BaO_2, in suspension.

$$BaO_2 + CO_2 + H_2O = BaCO_3 + H_2O_2.$$
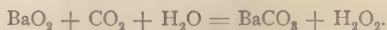
The insoluble barium carbonate may be separated by filtration, best

through asbestos filters. This solution may then be concentrated by evaporation on a water-bath, without much decomposition. In fact, it is more stable than formerly supposed.

The commercial solutions usually contain about three per cent. of H_2O_2. Ethereal or glycerin solutions are sold, containing 5 and 25 per cent. In its purest form it is a syrupy, colorless liquid, having an odor resembling that of chlorine or ozone, and a tingling metallic taste. It is still liquid at $-30°$ C. ($-22°$ F.), but at a temperature of $100°$ C. ($212°$ F.) it rapidly changes into water and oxygen. This change takes place slowly even at ordinary temperatures. In dilute solutions it is much more stable, and may be boiled without suffering decomposition. The solutions of this substance are decomposed by many fine metallic powders. In most of its reactions it acts as an oxidizing agent. Argentic oxide, however, is reduced to the metallic state by it.

Tests.—To the suspected solution add a little starch solution, then some potassium iodide, and finally a few drops of a solution of ferrous sulphate. If any hydrogen peroxide be present, a blue color will appear. Very delicate.

Uses.—Oxygenated water, or hydrogen dioxide, is used as a bleaching agent for the hair and skin, converting brunettes into blondes. It is often used to renovate old pictures, the whites of which have become dingy. It has been used as a disinfecting application to ulcers, in ozena, diphtheric and scarlatinal sore throats, or where the membrane has invaded the nose. It is also used as a test for pus in urine, with which it causes an effervescence. Mixed with ether, it forms the so-called " ozonic ether," used with tincture of guaiacum as a test for blood coloring-matter, with which this mixture strikes an indigo blue color.

OXYGEN COMPOUNDS OF THE ELEMENTS OF THE CHLORINE GROUP, OR GROUP VII.

Fluorine forms no oxides or hydroxides.

Chlorine and Oxygen.—There are two oxides of chlorine known :

Cl_2O, **Hypochlorous Oxide or Anhydride.**
Cl_2O_4, **Chloric Tetroxide or Chlorine Peroxide.**

They are unstable compounds, very prone to decomposition, and of little importance.

Hypochlorous Anhydride, Cl_2O, obtained by acting upon mercuric oxide with dry chlorine, is a blood-red mobile liquid below $20°$ C. ($68°$ F.).

$$HgO + 2Cl_2 = HgCl_2 + Cl_2O.$$

Above this temperature it is a yellowish, pungent gas, resembling chlorine in many of its properties. It is a more powerful bleaching and disinfecting agent than chlorine, owing to the ease with which it decomposes. Water dissolves 200 times its volume of the gas, forming a colorless solution of **hypochlorous acid.** It sometimes decomposes with a slight jar, or even spontaneously, separating into chlorine and oxygen. Hypochlorous acid is unimportant, but it forms a series of salts called **hypochlorites.** A solution of the sodium salt, **liquor sodæ chloratæ** (U. S. P.), (Labarraque's solution), potassium hypochlorite, **liquor potassæ chloratæ,** and calcium hypochlorite, occurring in **chlorinated lime,** are the most important compounds.

Chlorous anhydride, Cl_2O_3, has been shown to be a mixture of ClO_2 and free chlorine.

Chlorine tetroxide, Cl_2O_4, may be obtained, as a yellow, explosive gas, by treating potassium chlorate with strong sulphuric acid. It is a powerful oxidizing agent. Below —20° C. (—4° F.) it is an orange-red liquid. It forms no corresponding acid.

Chloric acid, $HClO_3$, and **perchloric acid,** $HClO_4$, are also known, but are very unstable, and, like those before mentioned, are powerful oxidizing agents. Potassium chlorate is the only salt of note, which will be described under potassium.

Bromine and Oxygen.—No oxides of bromine are known. There are, however, three acids known, corresponding to those of chlorine. They are **hypobromous acid,** HBrO, **bromic acid,** $HBrO_3$, and **perbromic acid,** $HBrO_4$. They are of little importance, and but one salt of the three acids is of interest to the physician, and that is **sodium hypobromite,** NaBrO, used as a reagent for the estimation of urea. It is prepared in solution by adding bromine to a solution of sodium hydroxide, taking care to keep the mixture cool by immersion in cold water.

$$2NaOH + Br_2 = NaOBr + NaBr + H_2O.$$
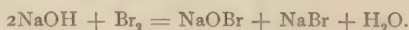
Iodine and Oxygen.—But one oxide of iodine is known with certainty—iodine pentoxide or iodic anhydride, I_2O_5. It is formed when iodic acid is heated to 170° C. (338° F.). Two oxygen acids are known—iodic, HIO_3, and periodic, HIO_4. The first is obtained by treating iodine with nitric acid, and the second by passing chlorine through a solution of iodine in water.

$$6H_2O + I_2 + 5Cl_2 = 10HCl + 2HIO_3.$$

The first, when pure, appears as a white crystalline solid, and the second as colorless crystals. Both are very soluble in water, are easily decomposed, and form corresponding salts.

SULPHUR.

$$S = 32 \ (31.85) \ (H = 1).$$

Specific Gravity, 2. Density of Vapor, 32. Melts at 115° C. (239° F.). Density of Vapor at 500° C. (932° F.), 95.94 = S_6; at 1000° C. (1832° F.), 31.98 = S_2.

Occurrence.—Sulphur was known to the ancients. It occurs in volcanic regions, and is brought mostly from Sicily and Iceland. The sulphur occurs native, mixed with clay, from which it is separated by distillation. This element also occurs as sulphates in the minerals gypsum, $CaSO_4 \cdot 2Aq$, and barite, $BaSO_4$, and as sulphides of iron,
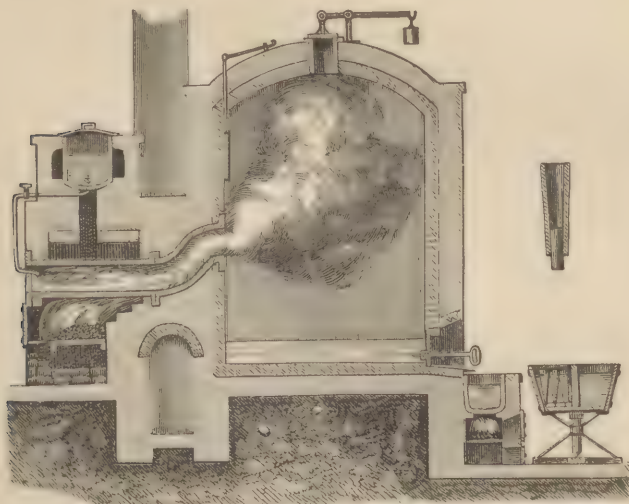
FIG. 53.—REFINING SULPHUR.

copper, nickel, and, in fact, with many of the metals; also as a precipitate from sulphur waters. The following equation explains its deposition from such waters:

$$2H_2S + O_2 = 2H_2O + S_2.$$
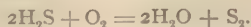
Preparation.—It is prepared from the native sulphur—found, mixed with more or less earth, in the volcanic regions of Sicily—by distilling it from the non-volatile impurities. A second distillation is necessary to prepare the refined sulphur of the market. The second distillation

is conducted in a retort, the vapor being carried into a large chamber (Fig. 53), where, if the process is conducted slowly, it collects in the form of a crystalline powder called **flowers of sulphur**, or **sulphur sublimatum** (U. S. P.). If the process is conducted more rapidly the chamber becomes hot, and the sulphur then condenses to a liquid at the bottom, whence it is drawn off into molds, forming ordinary **roll sulphur** or **brimstone**.

Sulphur is also obtained in some localities from iron pyrites, by piling it in heaps mixed with wood, to which fire is applied. The ore gives up a part of its sulphur, which melts and runs into cavities made under different parts of the heap. $3FeS_2 = Fe_3S_4 + S_2$.

Physical Properties.—Sulphur, in its ordinary form, is a lemon-yellow solid, melting at 115° C. (239° F.) and boiling at about 448° C. (839° F.), giving off a brownish-yellow vapor, which in condensing returns directly to the solid state. Sulphur is brittle, nearly tasteless, and odorless, a non-conductor of heat and electricity, and generates negative electricity when rubbed. It is insoluble in water, and almost so in alcohol. It is slightly soluble in aniline, phenol, benzene, benzine, and chloroform. The best solvent is carbon disulphide, 100 parts of which dissolve 37 parts of sulphur at ordinary temperatures.

Allotropic Forms.—Sulphur is capable of existing in four allotropic modifications—two crystalline, and two amorphous and plastic. The first variety is that found native, and occurs as octahedra. It is freely soluble in carbon disulphide, from which the crystals separate on evaporation. The second variety is produced by crystallization from sulphur melted at high temperatures. This variety occurs as yellowish-brown, transparent, monoclinic prisms, of sp. gr. 1.98, insoluble in carbon disulphide, and gradually changing into the first variety. Since it crystallizes in two distinct forms, sulphur is said to be **dimorphous.** Sulphur melts at about 115° C. (239° F.) to a yellowish liquid; on raising the temperature to about 200° C. (393° F.), it becomes viscid and dark colored, and can not be poured from the vessel; at a higher temperature, approaching its boiling point, it again becomes liquid. If sulphur, in this second liquid state, be suddenly cooled by pouring into cold water, it becomes a soft, plastic, transparent mass, capable of being molded like wax. This variety, like the preceding, gradually changes into the first variety, becoming opaque, yellow, and crystalline. The fourth variety is a white amorphous powder, formed along with flowers of sulphur when sulphur is distilled and suddenly cooled.

Chemical Properties.—When heated in the air, sulphur takes fire and burns with a pale blue flame, and evolves abundant fumes

of sulphurous anhydride, SO_2. It is generally strongly electronegative, and resembles oxygen in many of its compounds. In a few compounds it is electropositive. It unites directly with many of the metals, especially when in the melted state, some metals taking fire and burning readily in its vapor. It forms the basis of a large and useful class of compounds, many of which resemble in composition the corresponding compounds of oxygen.

Thus, carbon disulphide, CS_2 corresponds to carbon dioxide, CO_2. Corresponding to hydrogen oxide, H_2O, we have hydrogen sulphide, H_2S; and to cyanic acid, CNOH, we have sulphocyanic acid, CNSH. Corresponding to carbonic acid, H_2CO_3, we have sulphocarbonic acid, H_2CS_3.

Uses.—Sulphur is used in the arts, in the manufacture of sulphuric acid, H_2SO_4, as a bleaching agent for straw and woolen goods, and in the manufacture of matches and gunpowder. In medicine it is used as a parasiticide, and as a gentle laxative, although not so frequently as formerly. It is innocuous.

Official Forms.—(1) **Sulphur sublimatum,** commercial flowers of sulphur. (2) **Sulphur lotum,** washed sulphur. Flowers of sulphur usually contain a small quantity of sulphurous oxide, which is removed by digesting the powder for three days in a dilute solution of ammonia water, then thoroughly washing with water to remove the ammonia. (3) **Sulphur præcipitatum, lac sulphuris,** milk of sulphur, is prepared by boiling sublimed sulphur for one hour with freshly slaked lime suspended in water.

$$3Ca(OH)_2 + 6S_2 = 2CaS_5 + CaS_2O_3 + 3H_2O.$$
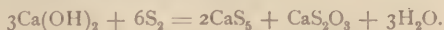
The filtered solution of CaS_5 and CaS_2O_3 is then diluted and treated with dilute hydrochloric acid as long as a precipitate forms.

$$2CaS_5 + CaS_2O_3 + 6HCl = 3CaCl_2 + 3H_2O + 6S_2.$$
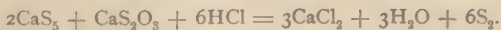
The calcium chloride, being very soluble, remains in solution. The sulphur must be thoroughly washed with water until free from acid. It is a fine, pale yellow, viscid liquid, easily suspended in water. (4) **Unguentum sulphuris** (U. S. P.) contains thirty per cent. of washed sulphur and seventy per cent. of benzoinated lard. Sulphur lotum enters into **pulvis glycyrrhizæ compositus.**

Sulphur and Hydrogen.—Two compounds of sulphur and hydrogen are well known—hydrogen sulphide, H_2S, and hydrogen persulphide, H_2S_2. The first only is of sufficient interest to merit description here. **Hydrogen sulphide, hydrosulphuric acid,** and **sulphuretted hydrogen** are synonymous terms. It is found in

volcanic gases, in some mineral springs, as a result of the decomposition of metallic sulphides, or of organic matter containing sulphur. At an elevated temperature, the two elements may be made to unite directly.

Preparation.—The usual method of preparing it is to act upon a sulphide, usually ferrous sulphide, FeS, with dilute sulphuric acid.

$$FeS + H_2SO_4 = H_2S + FeSO_4.$$

Properties.—H_2S is a colorless, transparent gas, of an unpleasant odor resembling that of rotten eggs, soluble in water, to which it imparts acid properties. It is somewhat heavier than air, its density being 17 and its sp. gr. 1.177. At a temperature of —70° C. (—94° F.), or under a pressure of 17 atmospheres at 10° C. (50° F.), it condenses to a colorless, mobile liquid, which at —85° C. (—121° F.) becomes an ice-like solid.

It burns with a blue flame, producing water and sulphurous oxide or anhydride, SO_2.

$$2H_2S + 3O_2 = 2H_2O + 2SO_2.$$
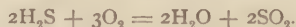
If the supply of oxygen is deficient, H_2O is produced, while the sulphur is deposited free. It is decomposed by chlorine, bromine, iodine, and oxidizing agents in general. It is also decomposed by sulphurous oxide. A solution of sulphuretted hydrogen does not keep long when exposed to the air. The oxygen of the air unites with the hydrogen of H_2S, forming water and causing the sulphur to be precipitated.

$$2H_2S + O_2 = 2H_2O + S_2.$$

When the gas is allowed to bubble through a solution of an alkaline hydroxide, the sulphur and oxygen exchange places, with the formation of a sulphydrate.

$$KOH + H_2S = KSH + H_2O.$$

When it is passed through a solution of a metallic salt, it forms, in many instances, a sulphide of the metal.

$$CuSO_4 + H_2S = CuS + H_2SO_4.$$

It is, on this account, largely used in the laboratory as a reagent for the separation of the metals from one another. Minute quantities of H_2S may be detected by the odor, or by the brown or black color the gas imparts to a paper moistened with a solution of plumbic acetate. Its principal use is that of a laboratory reagent.

Physiological Properties.—When inhaled, it is not an irritant, but a narcotic poison, even when largely diluted with air. According to Faraday, birds die in air containing $\frac{1}{1500}$ of it, and dogs in air containing $\frac{1}{800}$. According to Letheby, human beings can not live in an atmosphere containing more than one per cent. Its action is principally as a reducing agent upon the hæmoglobin of the blood, and prevents it from absorbing oxygen, although it probably does not combine with it. (Wurtz.) Hydrosulphuric acid is formed in the intestines from the decomposition of albuminous matters, especially when there is any impediment to digestion or to the onward movement of the intestinal contents. It also sometimes occurs in abscesses, in the urine, and in the bladder.

This gas is almost a constant ingredient in the gases of sewers and privy-vaults, existing free or combined with ammonium as ammonium sulphydrate. Poisoning by this gas may be acute or chronic. The latter is more common, producing a febrile state, with malaise and general debility. The fatal effects of sewer-air are sometimes due to this form of poisoning. Occasionally this gas is so concentrated in sewers that those who enter them suffer with acute poisoning, falling almost instantly, and, if not rescued, dying in a short time. The treatment, in such cases, should consist in giving the patient pure air, or oxygen, with brandy and water. Chlorine water, or a mixture of potassium chlorate and dilute hydrochloric acid, may be administered internally. When taken by the stomach it is almost harmless, and in the form of natural mineral water it is a popular remedy for rheumatism, gout, and certain skin diseases. Hydrogen disulphide is unimportant.

Sulphur with Chlorine, Bromine, and Iodine.—Sulphurous Chloride.—S_2Cl_2. A yellow, volatile, fuming liquid, having a powerful solvent power for sulphur and sulphuric chloride, and formed by distilling sulphur in an atmosphere of chlorine gas. A solution of sulphur in this liquid is used in vulcanizing rubber.

It is decomposed by water, but mixes with benzene and carbon disulphide. SCl_2 and several oxychlorides are known. **Bromine** unites directly with sulphur to form a red, unstable liquid, probably consisting mostly of S_2Br_2.

Iodine and **sulphur** combine directly when gently heated, even under water. When 80 parts of iodine and 20 parts of sulphur are heated together, they form a steel-gray, crystalline mass, S_2I_2, **sulphuris iodidum** (U. S. P. and Br.), said to be a powerful remedy in certain skin diseases. It melts at 60° C. (140° F.), and is insoluble in water. Other iodides have been described, but are unimportant.

14

**Sulphur and Oxygen.**—The following oxides of sulphur are known :

SO_2,	Sulphur dioxide, or Sulphurous anhydride.
S_2O_3,	Sulphur sesquioxide.
SO_3,	Sulphur trioxide, or Sulphuric anhydride.
S_2O_7,	Persulphuric anhydride.

Acids of Sulphur :

1.	H_2S,	Hydrosulphuric acid.
2.	H_2SO_2,	Hyposulphurous acid.
3.	H_2SO_3,	Sulphurous acid.
4.	H_2SO_4,	Sulphuric acid.
5.	$H_2S_2O_8$, or HSO_4,	Persulphuric acid.
6.	$H_2S_2O_3$,	Thiosulphuric acid. (This acid has not been isolated, but its salts are known.)
7.	$H_2S_2O_7$,	Pyrosulphuric acid. Nordhausen Acid.
8.	$H_2S_2O_6$,	Dithionic acid.
9.	$H_2S_3O_6$,	Trithionic acid.
10.	$H_2S_4O_6$,	Tetrathionic acid.
11.	$H_2S_5O_6$,	Pentathionic acid.

A few only of this large number of compounds are of sufficient importance to be described here.

Sulphurous Oxide or **Anhydride,** SO_2.—**Preparation.**—(1) It may be prepared by burning sulphur in the air. (2) By heating sulphuric acid with copper turnings, sulphur, or carbon.

$$Cu + 2H_2SO_4 = CuSO_4 + SO_2 + 2H_2O.$$
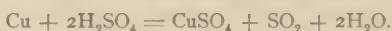
According to the U. S. P. and Br. P., charcoal is used :

$$2H_2SO_4 + C = 2H_2O + 2SO_2 + CO_2.$$

Physical Properties.—A colorless gas, having a pungent, suffocating odor and a disagreeable acid taste. It is very soluble in water, with which it combines to form an unstable sulphurous acid, **acidum sulphurosum** (U. S. P., Br. P.), emitting the odor of the gas.

$$SO_2 + H_2O = H_2SO_3.$$
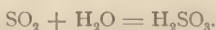
It is very soluble in alcohol. Specific gravity of the official acid, 1.035 at 15° C. (59° F.). The density of the gas is 32 ; sp. gr. (air = 1), 2.234. Below —10° C. (14° F.) it is a colorless, mobile liquid, which solidifies at —75° C. (—103° F.).

Acidum sulphurosum is a liquid containing not less than 6.4 per cent. by weight of the gas.

Chemical Properties.—SO_2 is non-combustible, and will not support combustion or respiration. It combines with water to form

sulphurous acid, and hence is an anhydride. Nascent hydrogen reduces it to H_2S and water. It is a valuable reducing agent, easily taking up oxygen to form sulphuric anhydride or acid. It is a bleaching, disinfecting, and deodorizing agent of considerable value. It bleaches moist vegetable colors, although not permanently destroying them. The colors may be restored by an alkali or by weak chlorine water. It is used principally for straw, silk, and woolen goods. Its bleaching action is due to its absorption of oxygen from water.

$$SO_2 + H_2O = H_2SO_4 + H_2.$$

The nascent hydrogen reduces the coloring-matter, with the formation of colorless compounds. It decomposes hydrogen sulphide and, when concentrated, destroys many forms of microscopic life, and is much used as a disinfectant of rooms after contagious diseases. Although not so active as chlorine, it is preferred, because it does not corrode metals or bleach fabrics, if dry. To apply it, close the room and burn about three pounds of sulphur for every 1000 cubic feet of air, leaving the room closed for from six to eight hours.

Sulphurous acid forms two series of salts, the neutral and the acid salts. They are used as antiferments or antizymotics.

Uses.—The sulphites and thiosulphates (hyposulphites) are used internally, in zymotic diseases, gastric fermentations, sarcinæ, etc. ; also locally, in erysipelas and poisoned wounds. The sulphites and thiosulphates of the alkaline metals are used for the same indications as the acid. Thiosulphate of sodium is prepared by digesting sulphur with sulphite of sodium. It is used in photography and electrometallurgy, as a solvent for the silver salts. Dose of the acid, 1 to 4 c.c. ($\text{m}$xv to f3j), largely diluted. Dose of sodium sulphite or thiosulphate, 0.65 to 3.0 (gr. x to gr. l).

Sulphuric anhydride, SO_3, is obtained by distilling **Nordhausen acid,** as white, silky prisms, hissing when dropped upon water, from the energy with which they combine. Melts at 18.3° C. (65° F.) and boils at 43° C. (110° F.). It does not redden dry litmus paper. It has a powerful affinity for water, absorbing it from the atmosphere. It is only of scientific interest.

Sulphuric Acid, Hydrogen Sulphate, Oil of Vitriol.—H_2SO_4 $= 97.82$. The commercial acid is prepared in large quantities directly from sulphur or iron pyrites. The process is conducted in large chambers lined with sheet-lead. Into these chambers sulphurous oxide pours from a furnace in which sulphur is burned or pyrites roasted, along with a free supply of air.

$$S_2 + 2O_2 = 2SO_2.$$
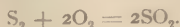
In the same furnace is placed a crucible containing sodium nitrate and sulphuric acid, for the purpose of preparing and volatilizing nitric acid, which is carried into the chamber with the SO_2 and air.

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3.$$

The nitric acid gives up a part of its oxygen to oxidize a portion of the SO_2 to SO_3.

$$2HNO_3 + 3SO_2 = 3SO_3 + H_2O + N_2O_2.$$
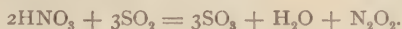
The SO_3 combines with the water thus produced, and with more water which is supplied by a jet of steam thrown constantly into the chamber.

$$SO_3 + H_2O = H_2SO_4.$$

The N_2O_2 has the power of taking up oxygen from the air and becoming N_2O_4,

$$N_2O_2 + O_2 = N_2O_4,$$

which in turn parts with this oxygen to oxidize a new quantity of SO_2.

$$N_2O_4 + 2SO_2 = N_2O_2 + 2SO_3.$$

Thus the process is kept up as long as the SO_2, air, steam, and N_2O_2 are supplied. The acid condenses with the water on the floor of the chambers, and when it reaches a sp. gr. of 1.55 (**chamber acid**) it is drawn off into large leaden pans and evaporated to a sp. gr. of 1.746 (**pan acid**), containing seventy-eight per cent. of H_2SO_4, when it begins to dissolve the lead. It is then drawn off into platinum stills and the concentration completed.

Properties.—The commercial acid is a heavy, corrosive, oily liquid, often of a brownish tint, and has a sp. gr. of 1.83 to 1.845. It mixes with water in all proportions, combining with a certain quantity to produce at first H_4SO_5, and finally orthosulphuric acid, H_6SO_6, with the evolution of considerable heat. The concentrated acid absorbs moisture, and is used as a desiccating agent. Gases, allowed to bubble through it, are deprived of their moisture. It chars organic matter and corrodes animal tissue. Paper dipped in a cooled mixture of two parts of the acid and one of water, and then quickly washed, is converted into **parchment paper.** Starch or cellulose, when boiled with the dilute acid, is changed, by hydrolysis, into glucose or grape-sugar, and cane-sugar into dextrose and levulose. In this action it behaves like the unorganized ferments, diastase. pepsin, trypsin, etc., and illustrates the so-called catalytic action of

certain bodies. The dilute acid is a solution of H_6SO_6 in water. On boiling this with the above-named bodies, it imparts a portion of its water to the organic body, and takes up more water from the solution to supply its place. Sulphuric acid is a powerful dibasic acid, forming a series of salts called **sulphates,** all containing the SO_4 group of atoms. It also forms a series of acid sulphates—$HKSO_4$, $HNaSO_4$. Owing to the powerful affinities of this acid, it usually removes the metal or positive radical from other acids and sets them free. It forms insoluble precipitates with solutions of barium, lead, strontium, and with calcium in concentrated solutions. This should be remembered in adding it to prescriptions. The other sulphates are soluble in water.

Medical Effects.—When dilute, it is **tonic** and **astringent.** Concentrated, or in large doses, it is a corrosive poison. Antidote: lime, magnesia, sodium bicarbonate, or other alkaline body; best given in milk.

Official Forms.—Acidum sulphuricum. (U. S. P., Br.). Specific gravity, 1.84. Used only in making other preparations. It contains not less than 92.5 per cent. by weight of absolute sulphuric acid. It is a colorless, inodorous, and very corrosive liquid, having an oily consistency and a very strong acid reaction. **Acidum sulphuricum dilutum** (U. S. P.). Specific gravity, 1.07 at 15° C. (59° F.), containing 10 per cent. H_2SO_4. Br. P., sp. gr. 1.094, containing 13 per cent. H_2SO_4. **Acidum sulphuricum aromaticum** (U. S. P., Br.) should contain about 18.5 per cent. of absolute sulphuric acid, or about 20 per cent. of the official acid. It is an alcoholic solution, containing also tincture of ginger and oil of cinnamon. It contains ethyl sulphuric acid.

$$\begin{matrix} H & - O \\ C_2H_5 & - O \end{matrix} > S = O_2.$$
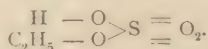
Tests for Sulphuric Acid and Sulphates.—1. Barium chloride gives a white precipitate, insoluble in all acids.

2. Lead acetate gives a white precipitate, slightly soluble in hot concentrated acids.

3. An insoluble sulphate may be detected by fusing it with some sodium and potassium carbonate, dissolving out the alkaline sulphate with water, and testing with barium chloride.

Fuming sulphuric, pyrosulphuric, or **Nordhausen sulphuric acid,** $H_2S_2O_7$, is obtained by distilling ferrous sulphate. The first portions are a white, crystalline solid, fusing at 35° C. (95° F.) and having the above composition.

The commercial acid is a brown, oily liquid, hissing when dropped

into water. Some chemists regard it as a solution of SO_3 in H_2SO_4. When heated, it gives off SO_3 and H_2SO_4.

$$H_2S_2O_7 = H_2SO_4 + SO_3.$$
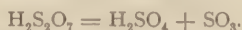
It is used in manufacturing alizarin, eosin, etc., and as a solvent of indigo. It forms a series of salts called disulphates or pyrosulphates.

The thiosulphuric acids are unimportant. Sodium thiosulphate is treated of among the salts of sodium.

Selenium and Tellurium.
Se, 78.87.   Te, 125.

These elements are rare and of no special interest to the physician or pharmacist.

GROUP V.—NON-METALLIC ELEMENTS,

OR

NITROGEN GROUP.

Nitrogen,	N	$=$	13.93. III or V.
Phosphorus,	P	$=$	30.79. III or V.
Arsenic,	As	$=$	74.44. III or V.
Antimony,	Sb	$=$	119.52. III or V.
Bismuth,	Bi	$=$	206.54. III or V.

Group Characteristics.—A well-defined group, with nitrogen at the negative end and bismuth at the positive. The atomic weights form a graded series from 13.93 to 206. The first is a gas; the second a volatile solid; the third a volatile, crystalline, metallic-looking body, showing a slight tendency to alloy with metals and combine with acids; the fourth less easily volatilized, crystalline, possessing a brilliant luster, alloying with metals, and showing a tendency to act the positive rôle with acids; the fifth, also crystalline, having a metallic luster, and showing more marked positive tendencies. They are all both triad and pentad, and form two series of compounds.

The following will exhibit the relations of some of the most important compounds:

| Hydrides.	Chlorides.	Oxides.	Sulphides.
NH_3	NCl_3 . . .	N_2O_3, N_2O_5	. . . . . .
PH_3	PCl_3, PCl_5	P_2O_3, P_2O_5	P_2S_3, P_2S_5
AsH_3	$AsCl_3$, $AsCl_5$	As_2O_3, As_2O_5	As_2S_3, As_2S_5
SbH_3	$SbCl_3$, $SbCl_5$	Sb_2O_3, Sb_2O_5	Sb_2S_3, Sb_2S_5
. . .	$BiCl_3$, . . .	Bi_2O_3, Bi_2O_5	Bi_2S_3, . . .

NITROGEN.

Symbol, N. Atomic Weight, 14. Valence, I, III, or V. Density, 14. Weight of one liter, 1.256 grams. Specific Gravity (air = 1), 0.971.

Occurrence.—It exists free in the air, mixed with oxygen and argon. It is also found free in the gases of the stomach, the large and small intestines, the blood, the urine, etc. Combined, it occurs as nitrates of potassium, sodium, and calcium; in ammonia and in vegetable and animal bodies of the proteid group.

It was discovered in 1772 by Rutherford, who called it "mephitic air."

Preparation.—It is prepared from the air by burning phosphorus in a confined space until the oxygen is removed (Fig. 54), or by passing air over copper or iron turnings heated to redness; the nitrogen prepared by both methods contains small quantities of other gases found in the air. To prepare it pure, heat ammonium nitrite, NH_4NO_2.

$$NH_4NO_2 + heat = 2H_2O + N_2.$$
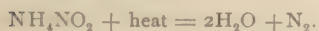
Properties. — A colorless, transparent, odorless, tasteless, incombustible gas, not a supporter of combustion or of animal respira-

FIG. 54.

tion. It is not poisonous; very sparingly soluble in water or alcohol. One part of water dissolves, at the ordinary temperature and pressure, 0.025 part of this gas. Chemically, nitrogen is characterized by its inertness. It unites directly with magnesium, boron, vanadium, and titanium. Indirectly, it forms a great number and variety of compounds, many of which are unstable. Under the influence of electrical discharges, nitrogen can be caused to unite with hydrogen to form ammonia, NH_3, and with oxygen to form nitrous oxide. From this source most of the nitrogenous products necessary to sustain plant life are primarily derived.
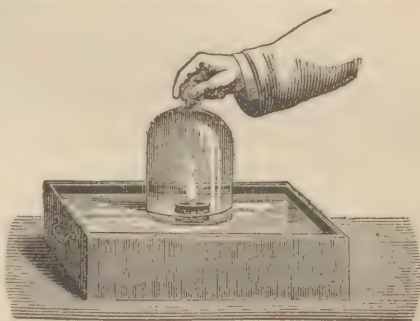
THE ATMOSPHERE.

The **atmosphere** is a colorless, invisible, odorless mixture of gases, which surrounds the earth. It is very elastic, and is therefore most dense nearest the earth's surface, upon which it exerts a pressure of about fifteen pounds to every square inch. Air was first weighed by Otto Gerecke. One thousand cubic centimeters of air at 0° C. and 760 millimeters of pressure weigh 1.293 grams. It is 14.44 times as heavy as hydrogen.

The **atmosphere** is composed principally of nitrogen and oxygen, mixed together in the proportion of 20.93 parts of oxygen, by volume, to 79.07 parts of nitrogen, and, by weight, 23 parts of oxygen to 77 parts of nitrogen.*

Although air is a mixture and not a definite compound, it is remarkably constant in composition. Regnault found in 233 analyses of air, at different times and places, that the percentage of oxygen by volume varied between 20.908 and 20.999. That air is a mixture is proved by : First, its gases are not present in the proportion of their atomic weights; second, an air answering to all the properties of the atmosphere can be made by a mechanical mixture of the gases; third, solvents for oxygen, as an alkaline solution of pyrogallic acid, remove this gas from the air ; fourth, each gas dissolves in water independently of the other, and with its own solubility ; thus, by expelling the air from water, by boiling, and analyzing it, we find it to correspond to that calculated from the known solubility of the two gases. (See p. 79.)

The analysis of the air expelled from water shows thirty-three per cent. of oxygen and sixty-seven per cent. of nitrogen; it is, therefore, much richer in oxygen than the atmosphere. Owing to the rapid diffusion of the gases, the disturbances in composition due to the respiration of animals and to manufacturing processes are soon restored. Besides the two chief gases found in the air, there are various other ingredients found in small quantities, as argon, watery vapor, carbon dioxide, ozone, ammonia, nitric and nitrous acids, hydrocarbons, solid particles of dust, sodium chloride, vegetable germs or spores, bacteria, etc. Air in which animals are confined also contains some organic matter, exhaled from their bodies. In the neighborhood of large cities, various other substances are poured into the air from manufacturing establishments.

The essential ingredients are oxygen, nitrogen, carbon dioxide,

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* The exact amount of argon, krypton, and neon present in air is not certainly known. These are included in the nitrogen in the above figures.

and watery vapor. The rest of those enumerated may be regarded as accidental, and not essential to the life of plants and animals.

Watery Vapor.—The proportion of watery vapor in the air varies considerably with the temperature and locality. The air is seldom saturated in the day-time, and contains less inland than near large bodies of water. The higher the temperature of the air, the more moisture it will hold; thus, at $0°$ C. ($32°$ F.) 1 cubic meter (1.3 cubic yards) is saturated by 5.4 gm. (83.3 grs.) of water, and at $25°$ C. ($77°$ F.), the ordinary temperature, it requires 22.5 gm. (347 grs.). Or, at $77°$ F. 1 cubic yard will be saturated by 267 grs. of water, and 1 cubic foot by about 10 grs. In reality, the air will seldom be found to contain more than 60 or 70 per cent. of this amount.* When 1 cubic meter (1.3 cubic yards) of an atmosphere saturated at $25°$ C. ($77°$ F.) is cooled down to $0°$ C. ($32°$ F.), it will deposit, as dew, rain, or frost, $22.5 - 5.4 = 17.1$ gm. (263.8 grs.). The temperature at which air begins to deposit its moisture, on being cooled, is called the **dew point.** The dew point will depend upon the amount of water actually present in the air. The amount of moisture is determined by passing a known volume of air through tubes containing calcium chloride, which absorbs the water. The increase in the weight of the tubes gives the weight of water. The amount of vapor in air varies from 0.3 to 1.6 per cent. by volume. The dampness of the air does not depend upon the amount of water it contains, but upon the degree of saturation. A cold, damp air, when heated, becomes dry; hence the necessity of supplying moisture to the heated air in our rooms in winter. A very dry air irritates the air-passages, produces dryness of the skin, and malaise. A very moist atmosphere checks evaporation from the skin and lungs, raises the bodily temperature, and soon becomes oppressive. A damp air favors the growth of many varieties of disease-producing organisms, as those of cholera, typhoid fever, and probably tuberculosis.

Carbon Dioxide.—The average amount of carbon dioxide, CO_2, in country air is 4 parts in 10.000, and varies from 3 to 6 parts. It is greater near large cities and manufactories; greater during the night than the day on land, and the reverse on the ocean. Plants remove it from the air in the day-time, and the cooler water at night absorbs more than the warmer water during the day. (See Carbon Dioxide.)

Ammonia.—This exists in the air, in very minute quantities, principally in the form of carbonate, the result of the decomposition of

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* By percentage of humidity, in meteorology, is meant the ratio between the actual moisture present and that required to saturate the air at that temperature.

15

animal and vegetable organic matters. It is especially evolved from urinals, privy-vaults, and horse-stables. It is washed out of the air by falling rain, and is taken up from the soil by plants.

Nitric and nitrous acids occur in extremely minute quantities, and are produced by the direct union of oxygen and nitrogen, in the presence of watery vapor, under the influence of discharges of lightning. They exist principally in combination with ammonium.

Hydrocarbons, the principle one of which is marsh-gas, are frequently found in the air of cities, coal-mines, wells, and swampy districts. Marsh-gas is produced by the decomposition of vegetable matter under water, and in some industrial processes.

Accidental Gases in the Air.—The gases generated in certain manufacturing processes are sometimes allowed to escape into the air. Some of these are harmless and others hurtful. Among the first class may be mentioned **carbon dioxide,** when not in too large quantities, and **ammonia.** To the second class belong **hydrogen sulphide, ammonium sulphydrate, sulphurous oxide** in large quantities, vapors of **mineral acids, carbon disulphide,** etc.

Hydrogen sulphide, or sulphuretted hydrogen. H_2S, is found in certain tunnels and mines, caused by the decomposition of iron pyrites. It is also found in the air of some marshes and of sewers.

The symptoms produced by breathing small quantities of this gas are those of debility and anemia ; in larger quantities, headache, vertigo, weak pulse, sweating, and prostration.

Ammonium sulphydrate, NH_4HS, produces nearly the same symptoms as hydrogen sulphide. It occurs in the air of sewers and privy-vaults. Both these substances are easily destroyed by chlorine or sulphurous oxide.

Sulphurous oxide, SO_2, unless in considerable quantities and in a closed room, does not seem to have any deleterious effect upon the workmen. In bleachers it sometimes produces irritation of the bronchial tubes.

Hydrochloric acid, nitric acid, and **chlorine** in considerable quantities are very irritating to the lungs and conjunctiva.

Carbon disulphide, CS_2, produces unpleasant and deleterious effects upon workmen exposed to air containing it, as headache, giddiness, nervous depression, and loss of appetite.

Suspended Matters.—A great variety of solid particles, or dust, are found in the air at all times. These consist of fragments of wood, textile fabrics, metals, etc., pollen of plants, spores of bacteria, etc. These suspended particles may be regarded as impurities, and many of them are injurious to health. Workmen in various trades are seriously affected by the dust to which they are exposed ; as miners, especially

of lead and coal ; grinders of metal, wool-sorters, rag-pickers, feather-dressers, etc. The irritation of the dust of these and other trades may cause chronic bronchitis, emphysema, phthisis, or chronic poisoning. Germs of various kinds are believed to cause many of the contagious and malarial diseases, and may be carried some distance in the air. Some of these germs seem to be easily oxidized, while others are very persistent. The best disinfectants for their destruction are free ventilation, and consequent dilution with dry air, chlorine, bromine, iodine, and sulphurous oxide.

Disinfectants, Germicides, Antiseptics, Deodorizers.— The presence of odors and organized "germs" in the air often requires the use of one of the above agents. **Disinfectants** are a class of bodies which are supposed to destroy the germs, and thus prevent them from causing their specific action either upon the human body or in decomposable organic bodies or solutions.

The most efficient of these is heat. Organized germs may be filtered from the air by passing it through cotton-wool ; or they may be removed by inclosing the air in a tight box or chamber the insides of which are moistened with glycerin (Tyndal). Among the disinfectants most used are ozone, chlorine, bromine, iodine, formaldehyde, sulphurous oxide ; the chlorides of mercury, zinc, aluminium, magnesium, and calcium ; potassium chlorate, potassium permanganate ; carbolic, boric, cresylic, and sulphuric acids ; thymol, menthol, camphor, etc.

Antiseptics are agents which retard or entirely prevent putrefaction or growth of microscopic organisms. While **disinfectants** destroy the cause of infection, **antiseptics** prevent the development of these causes. Low temperature retards putrefaction, and is, therefore, an antiseptic agent. These two terms are frequently used interchangeably.

A *germicide* is an agent which has the power of killing the germs, and thus preventing their growth. A disinfectant destroys the infectious properties of septic matter, whether these be due to germs or to some other agent.

Asepsis is a condition of entire absence of any germs or cause of infection. **Deodorizers** are bodies used to destroy offensive odors. They may be either solid, liquid, or gaseous. **Solids**—dry earth, lime, charcoal, ferrous sulphate ; carbolates of calcium, sodium, and magnesium. **Liquids**—solutions of plumbic nitrate (Ledoyen's fluid), zinc chloride (Burnett's fluid), potassium or sodium permanganate (Condy's fluid) ; a mixture of copper and zinc sulphates (Lenande's disinfectant) ; solutions of ferric chloride, of ferrous sulphate, hypochlorites, etc., are among the best known. **Gases**—pure

air, ozone, chlorine, bromine, and sulphurous oxide are the most effect-
ive. Fumigations with tar, herbs, and various aromatic substances
only disguise the offensive odors, but do not destroy them.

The ordinary offensive odors are due to hydrogen sulphide, H_2S,
ammonium sulphydrate, NH_4HS, phosphorous hydride, PH_3, and com-
plex ammonium compounds. Chlorine, ozone, and nitrous oxide
will destroy these gases by oxidation, and thus destroy the odor.

It should be remembered that these odors, in themselves, may not be in any degree
injurious to health when in small quantity, but they serve to warn us of the presence
of products of putrefaction which accompany them, and which are injurious. The
fact that efficient disinfection of the air can prevent the spread of the contagion of
disease is well known. Chlorine and sulphurous oxide are the two agents most in
use, and of these the former is very much to be preferred, but the latter is used for
furnished rooms, because of its less destructive action on articles exposed to it.

It is doubtful whether organized germs in the air can be destroyed by any disin-
fectants, except in tightly closed rooms. The attempt to disinfect the air of rooms
with the various so-called "disinfectants" of the market is worse than useless. It
engenders a feeling of security where there is none. These floating germs can cer-
tainly stand as much as, and in most cases more than, man, and therefore no room can
be disinfected while it is occupied by human beings. The author has found by
experiment that most of the ordinary antiseptics, when diffused through the air of an
ordinary room, are almost without action on putrefactive bacteria, unless the quantity
be great enough to make the air irrespirable.

The following table shows the amount of water it is necessary to
add to one part of the substance named, which barely permits the
development of bacteria in meat-infusions, according to M. Jalan de
la Croix :

| 1 Part.	Water, Parts.	1 Part.	Water, Parts.
Alcohol,	. 30	Oil of mustard,	5,734
Chloroform,	134	Sulphurous acid,	7,534
Borax,	107	Aluminium acetate,	7,535
Eucalyptol,	308	Salicylic acid,	7,677
Phenol (carbolic acid),	1,002	Mercuric chloride,	8,358
Thymol,	2,229	Calcium hypochlorite,	13,092
Potass. permanganate,	3,041	Sulphuric acid,	16,782
Picric acid,	3,041	Iodine,	20,020
Borated sodium salicylate,	3,377	Bromine,	20,875
Benzoic acid,	4,020	Chlorine,	34,509

Devaine says of iodine that 1 part to 12,000 destroys the con-
tagion of charbon and 1 : 10,000 that of septic blood. Billroth says
mercuric chloride 1 : 20,000, thymol and benzoate of sodium
1 : 2000, and benzoic acid and creasote 1 : 1000 prevent the
development of bacteria. Koch says of mercuric chloride that 1 :
15,000 kills most micro-organisms and 1 : 1000 destroys resting
spores. Formaldehyde 1 : 15,000 destroys most living germs.

The results of different experimenters are so widely discordant that we make no attempt to reconcile them. The following table represents the results of experiments with commercial disinfectants. The first column gives the percentage of the agent necessary to kill **anthrax** and **bacillus subtilis.** The second gives the percentage of the agent which failed to produce this result :

LIST OF COMMERCIAL DISINFECTANTS (*Sternberg*).

NAME.	PERCENTAGE IN, WHEN ACTIVE IN TWO HOURS.	PERCENTAGE IN, WHICH FAILED IN TWO HOURS.
Little's Soluble Phenyle, ...	2	1
Labarraque's Solution (U. S. P.), . . .	7	5
Liquor Zinci Chloridi (Squibb's), . . .	10	7
Feuchtwagner's Disinfectant, ...	10	8
Labarraque's Sol. (Frerè, Paris), . . .	15	10
Phenol Sodique, ...	15	10
Platt's Chlorides, ...	20	15
Gerondin Disinfectant, ...	25	15
Williamson's Sanitary Fluid, ...	25	20
Bromo-chloralum, ...	25	20
Blackman's Disinfectant, ...	30	20
Squibb's Impure Carbolic Acid, ...	. .	50
Bouchardat's Disinfectant, ...	. .	50
Phenol Sodique (Paris), ...	. .	50
Listerine, ...	. .	50
Hypochlorite of Sodium or Calcium, Available Chlorine, ...	0.25	. .

Nitrogen and Hydrogen.—Ammonia.—Source.—From the decomposition of animal or vegetable matter containing nitrogen, either spontaneously or by the aid of heat. First prepared by distilling camels' dung, in Libya, near the temple of Jupiter Ammon. When horns, clippings of hides, or coal are heated in closed retorts, ammonia is given off. The principal source, at present, is from the destructive distillation of coal in gas-works. Coal contains about two per cent. of nitrogen, which is mostly given off as ammonia. The "ammonia liquor" is treated with hydrochloric acid and evaporated to dryness, when an impure ammonium chloride, **sal ammoniac,** is obtained. This may be purified by recrystallization or sublimation. This salt, heated with lime, CaO, gives off its ammonia. This is conducted through a series of Woulfe bottles containing water, in which the gas dissolves, forming aqua ammonia, from which the other compounds may be prepared.

$$2NH_4Cl + CaO = 2NH_3 + H_2O + CaCl_2.$$
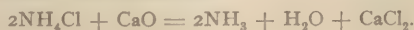
Properties.—Ammonia is a colorless, transparent, pungent, irrespirable gas. It does not support combustion or burn in the air, but burns with difficulty in an atmosphere of oxygen, forming water and free nitrogen. It has a strong alkaline reaction on moistened litmus paper, which, however, is not permanent, owing to the volatility of the ammonia.

It is lighter than air. Liquefies at —40° C. (—40° F.); or at 10° C. (50° F.), under a pressure of 6.5 atmospheres, to a colorless liquid of sp. gr. 0.76, which solidifies at —75° C. (—103° F.).

It is very soluble in water; one volume of water at 15° C. (59° F.) dissolves 783 volumes of the gas with the evolution of heat, forming the solution known as **aqua ammoniæ**, which may be regarded as a solution of ammonium hydroxide, NH_4–O–H, in water.

This solution, on being heated, gives up most of the gas again. **Aqua ammoniæ fortior** (U. S. P.) contains twenty-eight per cent., by weight, of the gas, and has a sp. gr. of 0.901 at 15° C. (59°F.). **Ammoniæ liquor fortior** (Br. P.) contains 32.5 per cent. of gaseous NH_3 dissolved in water. **Aqua ammoniæ** (U. S. P.), **Liquor ammoniæ** (Br. P.), contains ten per cent., by weight, and has a sp. gr. of 0.96 at 15° C. (59° F.). It is a colorless, transparent liquid, with a pungent odor and an alkaline taste and reaction. It forms, by direct union with the acids, a series of salts containing the compound radical NH_4, called **ammonium.** Ammonia is volatile, and hence it is sometimes known as the **volatile alkali.** The compounds of NH_4 closely resemble those of Na and K, and will be considered with them. Strong solutions of the gas act as a caustic upon animal tissues, and are, therefore, corrosive poisons.

Composition.—This may be determined by decomposing the gas by passing a series of electric sparks through a quantity of it inclosed in a eudiometer-tube over mercury. The volume increases until double the original volume is reached. By introducing a quantity of oxygen equal to three-fourths that of the ammonia used, and igniting the gases by the same spark, the hydrogen and oxygen combine, and after condensing leave the nitrogen, which occupies one-half the original volume, or one-fourth the volume of the mixed hydrogen and nitrogen, after the decomposition. It is thus shown to be composed of one-fourth nitrogen and three-fourths hydrogen.

We may also arrive at the same result in the following manner:

Prepare a glass tube of about 1 cm. (⅖ of an inch) caliber, closed at one end. Through the stopper in the open end pass a funnel tube drawn to a point and provided with a stopcock. Fill the tube with pure, dry chlorine, and insert the cork. Fill the funnel tube with strong ammonium hydroxide solution, open the stopcock, and allow a portion of the liquid to enter the tube. The chlorine decomposes the ammonia gas,

combining with its own volume of hydrogen and setting free the nitrogen in combination with it. By removing the stopper under water, the latter will rise to fill the tube, excepting that portion occupied by the nitrogen, which will be found to be one-third of the whole tube.

Now, as the chlorine combined with its own volume of hydrogen, or with the tube full, and left one-third of that volume of nitrogen, it is easy to see that the ammonia was composed of three parts by volume of hydrogen and one part of nitrogen. Since gaseous molecules all occupy the same space, three molecules of hydrogen and one of nitrogen form two of ammonia:

$$3H_2 + N_2 = 2NH_3.$$
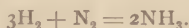
The compounds of ammonium with acids will be considered under the head of Salts of the Alkaline Metals. The compound or derived ammonias will be considered in Part IV.

Tests.—Odor. Fumes with HCl. Moistened red litmus paper is changed to blue by it. For Nessler's test, see page 149.

Hydronitric acid, or **hydrazoic acid,** HN_3, $H - N {\nearrow N \atop \searrow N}$, is a colorless gas, having a penetrating, unpleasant odor and an acid reaction.

Its sodium salt is prepared by boiling benzoyl-azo-imid with sodium hydroxide.

$$C_6H_5 . CON {\nearrow N \atop \searrow N} + NaOH = C_6H_5 . COONa + Na - N {\nearrow N \atop \searrow N} + H_2O.$$
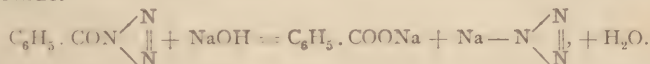
It forms a series of salts with the metals resembling the cyanides, chlorides, bromides, and iodides.

It unites with ammonia to form ammonium nitride.

$$NH_3 + HN_3 = NH_4N_3.$$

Nitrogen Chloride.—NCl_3. When chlorine **in excess** is made to act upon ammonia, the chlorine at first sets free nitrogen, and forms some ammonium chloride; the excess of chlorine then acts upon the ammonium chloride, to form nitrogen chloride, an explosive of great power.

$$NH_4Cl + 3Cl_2 = NCl_3 + 4HCl.$$

Properties.—A yellow, oily liquid, insoluble in water, possessing a disagreeable, irritating odor. Sp. gr. = 1.653. It is very explosive, and, in contact with any combustible matter, explodes spontaneously. It should not be prepared in large quantities.

Nitrogen Iodide.—NHI_2 or NI_3. **Preparation.**—By lightly triturating iodine in a mortar with strong ammonium hydroxide, or by pouring an alcoholic solution of iodine into strong ammonia water.

Properties.—A brownish-black solid, insoluble in water. When spread out on filter-paper and dried, it explodes with the slightest touch, or by a gentle breeze; the explosion, however, is not nearly so violent as that of the chlorine compound.

Nitrogen and Oxygen.—Five oxides of nitrogen are known, whose names, graphic formulæ, and corresponding acids are as follows:

Nitrous Oxide,   . . . $N-O-N$ Hyponitrous Acid, $H-O-N$

Nitric Oxide,   . . . $O\equiv N$ —— $N\equiv O$

Nitrous Anhydride, . $O\equiv N -O-N\equiv O$ Nitrous Acid, $H-O-N\equiv O$

Nitric Peroxide, } $\{ O= \atop O= N-o-N\equiv o$
or Tetroxide, }

Nitric Pentoxide, } $\{ O= \atop O= N-o-N {=O \atop =O}$ Nitric Acid, . $H-O-N{-O \atop -o}$
or Anhydride, }

Nitrous Oxide, Hyponitrous Oxide, Laughing-gas. Nitrogen Monoxide. Nitrogen Protoxide.—N_2O. Discovered in 1776 by Priestly. Anesthetic effect first discovered by Sir Humphrey Davy. First used in dentistry by Wells, of Hartford, Conn. First came into notice as an anesthetic in 1863.

Preparation.—By gently heating ammonium nitrate in a retort similar to that represented in figure 46, when it decomposes into nitrous oxide and water.

$$NH_4NO_3 = N_2O + 2H_2O.$$
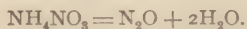
When prepared for anesthetic purposes, care should be exercised to keep the temperature of the retort between 210° C. (410° F.) and 250° C. (482° F.), as below the former the decomposition does not take place, but the salt sublimes; while above the latter, nitrogen dioxide and trioxide are generated. As an additional safeguard, the gas should be caused to bubble through solutions of sodium hydroxide and ferrous sulphate, to remove these higher oxides.

Properties.—A colorless, odorless, sweetish-tasting gas, slightly soluble in water, more so in alcohol. Density, 21.85; sp. gr., 1.527. Under a pressure of 50 atmospheres at 7° C. (45° F.) it condenses to a colorless liquid, which resumes the gaseous state as soon as the pressure is removed, the temperature sinking so low as to freeze a portion of the liquid into a white, snow-like solid. Sp. gr. of liquid, 0.908. Boiling point, —88° C. (—126° F.). Freezing point about —101° C. (—150° F.). It is neutral in reaction—i. e., neither acid nor alkaline. It supports the combustion of bodies very much like oxygen; this is due to the fact that the heat of the burning body

decomposes the gas, giving an atmosphere about them containing twice as much oxygen as ordinary air. For anesthetic purposes, the liquefied gas is now sold in wrought-iron cylinders, provided with a stopcock, so that the gas can be drawn from the cylinder as needed.

Physiological Effects.—Nitrous oxide causes, when first inhaled, an exhilaration, then anesthesia, and finally asphyxia. It will not support the respiration of plants or animals. It seems to act partly by excluding air and partly by its direct effect upon the nervous system. It does not enter into any chemical combination in the blood, but simply dissolves in this fluid. When mixed with oxygen and administered under an increased pressure, the anesthesia may be kept up for a long time with safety. Deaths from its inhalation are rare. It does not undergo decomposition in the blood. It is much used for short operations, and especially for the extraction of teeth, opening abscesses, felons, etc. Recovery is prompt and complete within a few minutes after its withdrawal. A solution in water containing five volumes of the gas has been administered internally.

Hyponitrous Acid.—HNO. This acid may be prepared by the action of hydrochloric acid on the silver salt.

$$AgNO + HCl = AgCl + HNO.$$

The potassium salt, KON, is formed by the action of sodium amalgam on potassium nitrite or nitrate ; preferably the former :

$$2KONO + 2H_2 = 2KON + 2H_2O.$$

The silver salt is a yellow, almost insoluble powder.

Nitric Oxide or Nitrogen Dioxide.—NO or N_2O_2. Prepared by the action of nitric acid upon copper.

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + N_2O_2 + 4H_2O.$$
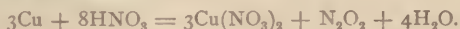
Properties.—A colorless, transparent gas, very sparingly soluble in water, more soluble in alcohol. Density, 15 ; sp. gr., 1.039.

The density would make the molecular weight 30 and the formula NO, which is anomalous, as in this case nitrogen must be considered as a dyad. The ordinary laws of valence would make it N_2O_2. It is probable that at lower temperatures this is the proper formula, and at the higher temperature dissociation takes place, N_2O_2 splitting up into NO, as has been proven to occur in the case of N_2O_4.

By cold and pressure the gas has been reduced to a liquid. Bodies which evolve considerable heat in burning—as phosphorus, for example —burn in this gas, first decomposing it and then uniting with its oxygen. In contact with free oxygen, or air, it takes up this gas and is converted into N_2O_4 or N_2O_3, according to the amount of oxygen

present. In both cases it gives a reddish-brown colored gas. The gas may be used as a test for free oxygen. It is rapidly absorbed by a solution of ferrous sulphate, to which it imparts a deep brown color. Its action on the economy is not known. It forms no corresponding acid.

Nitrous Anhydride.—N_2O_3. Prepared by the direct union of nitric oxide, N_2O_2, and oxygen, mixed in the proportion of two of the former to one of the latter. Also, by warming nitric acid with starch or arsenious acid, and by the action of nitrogen peroxide on cold water.

$$2N_2O_4 + H_2O = N_2O_3 + 2HNO_3.$$
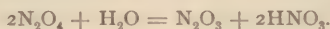
Properties.—A dark blue liquid, boiling at 0° C. (32° F.), with partial decomposition into N_2O_2 and N_2O_4, which recombine on cooling. It combines directly with water, producing nitrous acid, HNO_2, which, on warming, decomposes into nitric acid and nitric oxide.

$$3HNO_2 = HNO_3 + N_2O_2 + H_2O.$$

As will be seen from the above, this oxide is very unstable.

Nitrous Acid and Nitrites.—The acid is not known in a pure state, but it exists in solution, and several of its salts are known. The nitrites are formed by heating the nitrates, when they give off a part of their oxygen. The action is rendered easier if lead or some other oxidizable metal be added to the fusion. The nitrites are produced in nature by the oxidation of nitrogenous organic matter, accompanied by certain forms of microscopic life. Such nitrification takes place in waters polluted with organic matter, and normally in the soil. The acid then combines with bases found in the water or the soil. The presence of nitrites in water is, for this reason, looked upon as an evidence of previous contamination with nitrogenous organic matter. Further oxidation leads to the formation of nitrates in the same circumstances. The addition of a mineral acid to a nitrite sets free reddish-brown fumes. A solution of argentic nitrate forms a precipitate with cold, not too dilute, solutions of an alkaline nitrite. These two reactions distinguish these salts from the **nitrates.** The reddish fumes, above mentioned, are strong oxidizing agents, and set free iodine from potassium iodide. A solution of boiled starch, with which iodine forms a deep blue color, with a solution of potassium iodide and dilute sulphuric acid, are used as a test for nitrites in solution.

Nitrous acid and the nitrites act as reducing agents upon an acid solution of potassium permanganate, and decolorize this latter salt. The nitrites can be taken up by plants and elaborated into their structure, and hence are valuable fertilizers.

Nitrogen Peroxide, Nitrogen Tetroxide, Nitrogen Dioxide.
—N_2O_4. It may be prepared by mixing equal volumes of nitric oxide and oxygen,

$$N_2O_2 + O_2 = N_2O_4,$$
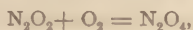
or, more easily, by heating dry plumbic nitrate in a retort, and passing the vapors into a cooled receiver, where they condense into a liquid:

$$2Pb(NO_3)_2 = 2PbO + 2N_2O_4 + O_2.$$
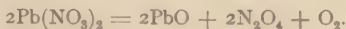
Composition.—N_2O_4 appears to exist in a pure state only at temperatures below 0° C. (32° F.). The liquid is colorless at these temperatures, but at its boiling point is yellow in color, owing to partial dissociation into NO_2, which is complete at about 150° C. (302° F.).

The gas is always reddish-brown in color, due to the presence of NO_2, while N_2O_4 is colorless. The density of the gas at 26° C. (78.8° F.), the boiling point of the liquid, is 38, and contains 20 per cent. of NO_2. On raising the temperature the density diminishes, and finally becomes constant at 150° C. (302° F.), and equals 23. This density corresponds to $NO_2 = 46$. This phenomenon of dissociation is frequently noticed in determining the density of bodies at temperatures much above their boiling points. The laws of valence seem to hold, in these cases, only at the lower temperatures, at which dissociation does not take place; hence the confusion that exists in the formulæ of such bodies as—

N_2O_4 or NO_2, N_2O_2 or NO, Hg_2Cl_2 or $HgCl$, etc.

Properties.—Cold water, in small quantity, decomposes it into N_2O_3 and HNO_3, while in larger quantities and with alkaline hydroxides it forms nitrous and nitric acids, or their salts.

The tetroxide, N_2O_4, and the dioxide, NO_2, both act as strong oxidizing agents, setting iodine free from the iodides.

Nitric Anhydride and Acid.—N_2O_5 and HNO_3. **Nitric anhydride** is a white, crystalline solid, fusing at 30° C. (86° F.) and boiling at 47° C. (116.6° F.). Obtained by treating dry silver nitrate with chlorine, or by the removal of water from fuming nitric acid by the action of phosphoric anhydride, P_2O_5. The oxide is unstable, and has a strong affinity for water, with which it forms nitric acid. It has no special use.

Nitric acid, Aqua Fortis, Acidum Nitricum (U. S. P., Br.), HNO_3, is the most important of the acids of nitrogen. It does not occur free, but as nitrates widely disseminated. It is usually prepared, commercially, by the action of sulphuric acid upon potassium or sodium nitrate, in glass or cast-iron retorts.

$$NaNO_3 + H_2SO_4 = HNaSO_4 + HNO_3.$$
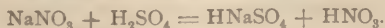
The arrangement of the iron retorts (A) and the stoneware condensers (B) are shown in section in figure 55. The sodium nitrate

and an equal weight of sulphuric acid is run in through the stoppered openings at the back. The iron is protected from the acid by a lining of fire-clay. When heat is applied to the retort, the nitric acid distils over and condenses in the stoneware Woulfe bottle, B, which is kept cool by cold water.

It is also formed in small quantities by the passage of electric discharges through a mixture of nitrogen and oxygen. This takes place in the air by the passage of flashes of lightning, probably by the oxidizing action of the ozone generated by these phenomena. The nitrates are formed in the soil and natural waters by the oxidation of organic matter, called nitrification, and is induced by certain microscopic organisms called nitrifying bacteria. In some
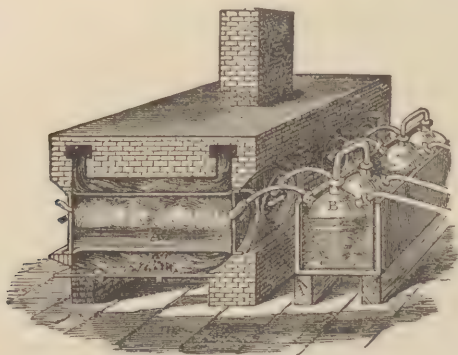
FIG. 55.

localities this process is conducted artificially. (See Potassium Nitrate.)

The commercial acid, prepared as above, contains sulphuric acid, traces of iron, the oxides of nitrogen, and chlorine. It is purified by redistillation with plumbic nitrate, which retains the impurities and allows only the pure acid to distil over.

Properties.—The pure acid is a colorless, rather heavy, fuming liquid, having a sp. gr. of 1.52, boiling at 86° C. (186.8° F.), and solidifying at —40° C. (—40° F.). The sp. gr. and boiling point of the diluted acid vary with the proportion of acid present. When strongly heated, or on exposure to light and air, the acid turns yellow and is decomposed into nitric tetroxide, N_2O_4, water, and oxygen.

Nitric acid readily gives up a portion of its oxygen, and thus acts as

a strong oxidizing agent, attacking and destroying vegetable and animal tissues and coloring matters. It is sometimes used as a cauterizing agent, first producing a yellow stain, then destroying the tissue. While it oxidizes most organic bodies, it enters into the composition of others, forming substitution products. Thus glycerin, cotton, sugar, etc., when treated with it, form explosive substitution products. Most metals dissolve in the acid, forming nitrates; gold and platinum are exceptions. The non-metals or negative elements are usually oxidized by it. Metallic iron dissolves readily in the dilute acid, but when plunged into the strong acid it assumes a condition known as the **passive state**; if now it be put into dilute acid, it is not attacked by it until a piece of platinum is brought into contact with it, or by some other means the passive condition is destroyed. **Nitrosonitric** acid is a yellow, partially decomposed acid, containing nitric peroxide, N_2O_4. **Aqua regia** is prepared by mixing together four parts of hydrochloric and one of nitric acid; it soon assumes a yellowish-red color, and has the power to dissolve gold, platinum, and other metals, with the formation of chlorides.

Fuming Nitric Acid.—A reddish-brown acid. Sp. gr., 1.525. Containing N_2O_3 or N_2O_4. Used as a powerful oxidizing agent.

Official Forms.—**Acidum Nitricum.**—Sp. gr., 1.414 at 15° C. (59° F.). Contains 68 per cent. of HNO_3.

Acidum nitricum dilutum (U. S. P.) is prepared by adding 5.8 (Br. P., 4.2) parts of distilled water to 1 of the above acid. Sp. gr., 1.057 at 15° C. (59° F.), and contains 10 per cent. of HNO_3. Used for internal administration. Dose, ♏ v to ♏ xv.

Tests.—1. Add to the suspected liquid some ferrous sulphate, and pour the mixture on strong sulphuric acid in a test-tube. A black, brown, or reddish zone at the point of contact of the two liquids indicates nitric acid.

2. Heat the suspected solution with a few drops of sulphuric acid faintly colored with indigo, when, if nitric acid or a nitrate be present, the blue color will disappear.

3. The strong acid imparts a deep-red color to the alkaloid brucine.

4. When heated with copper turnings, the liquid assumes a green color and evolves reddish fumes. When the acid is in combination, a stronger acid must be added to set it free, as in test 2.

Physiological Effects.—In small quantities, well diluted, it is a stomachic tonic, and augments the secretion of urine. It seems to be mostly decomposed in the body, but a small quantity may pass into the urine as nitrates; it acts, therefore, as an oxidizing agent. The strong acid is a corrosive, violent poison, first staining the tissues and vomit, with which it comes in contact, a bright yellow color, and

then corroding them. These stains will be found on the tongue and fauces in cases of poisoning by this acid.

Antidotes.—Milk of lime, magnesia, or other alkalies well diluted, followed by sustaining treatment.
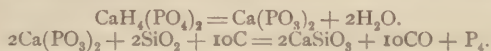
PHOSPHORUS.

$$P = 31.$$

Density of Vapor, 62. Molecular Weight, $124 = P_4$. At Very High Temperatures, Density, 31, and Molecular Weight, $62 = P_2$.

Occurrence.—Discovered by Brandt, in 1669, in urine ; and by Gahn, in bones, in 1769. It does not occur native, but as phosphates, and in organic substances. The most common mineral is calcium phosphate, $Ca_3(PO_4)_2$, derived from the bones of prehistoric mammals.

Preparation.—Phosphorus is usually prepared from the ash of burnt bones, in which it exists as tricalcium phosphate, $Ca_3(PO_4)_2$. By treating the ash with sulphuric acid, it is first converted into a soluble monocalcium phosphate, sometimes called superphosphate.

$$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4.$$
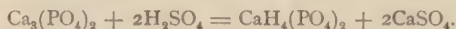
The $CaH_4(PO_4)_2$ is dissolved in water and drawn off, leaving the insoluble $CaSO_4$ in the vat. This solution is evaporated to dryness, after adding powdered charcoal and sand, and then transferred to a retort, whose beak dips under water. The retort is then gradually heated to a high temperature, when the $CaH_4(PO_4)_2$ is first dehydrated and converted into calcium metaphosphate, $Ca(PO_3)_2$, and water, and then undergoes reduction under the action of the carbon and sand as follows :

$$CaH_4(PO_4)_2 = Ca(PO_3)_2 + 2H_2O.$$
$$2Ca(PO_3)_2 + 2SiO_2 + 10C = 2CaSiO_3 + 10CO + P_4.$$

The free phosphorus distils over and condenses under the water as an impure article, which is purified by redistillation, or by fusing it under water with sulphuric acid and potassium dichromate. It is then cast into sticks, in molds.

Physical Properties.—Phosphorus is met with in several distinct allotropic states.

The ordinary form is a translucent, waxy-looking solid, which, at ordinary temperatures, is tenacious and of about the consistency of wax ; but at 0° C. (32° F.) and below it becomes brittle. It melts under water at 44° C. (111° F.) and boils at 290° C. (554° F.). By the action of light it soon becomes coated with a whitish or reddish

layer, probably an oxide. Its sp. gr. is 1.83 at 10° C. (50° F.). It shines in the dark, and, when exposed to moist air, emits the odor of ozone. It is insoluble in water and alcohol, but soluble in ether, benzene, petroleum, and in the fixed and essential oils. The best solvent is carbon disulphide. From this solution it separates in the form of octahedral and dodecahedral crystals. When a portion of the solution is poured upon filter-paper and allowed to evaporate spontaneously, it takes fire when the evaporation of the solvent is complete.

Red or **amorphous phosphorus** is a reddish-brown amorphous powder, of sp. gr. 2.14, insoluble in carbon disulphide; it does not alter in the air, and does not show the phosphorescence in the dark. While ordinary phosphorus is very poisonous, even to workmen handling it, this variety is entirely harmless. When heated to 260° C. (500° F.) it does not melt, but gradually sublimes. The vapor is converted into the ordinary form, which takes fire in presence of air.

Red phosphorus is prepared by heating the ordinary variety, for about thirty-six hours, to a temperature of from 250° C. (482° F.) to 300° C. (572° F.) in an atmosphere of hydrogen, carbon dioxide, or in an exhausted iron vessel. The mass is then washed with carbon disulphide or boiled with a solution of sodium hydroxide, to remove any of the ordinary variety remaining.

Other varieties of phosphorus have been formed. The **metallic** form is prepared by heating the red variety in a sealed tube to 500° C. (932° F.), when black, metallic-looking, microscopic needles sublime into the cooler portions of the tube. The sp. gr. of this variety is 2.34, and it is less active than the red variety.

Chemical Properties.—The most characteristic property of phosphorus is its ready oxidation. If the ordinary variety be heated to 60° C. (140° F.) in contact with air, it takes fire and burns with a brilliant flame, and evolves a voluminous white cloud of phosphoric pentoxide. It may be burned under warm water by throwing a jet of oxygen upon it.

It must be kept under water to prevent it from taking fire spontaneously. When fragments partly covered with water are exposed to the air, white fumes are seen to rise from them which contain ozone, hydric peroxide, and possibly ammonium nitrite, NH_4NO_2. This ozone is the cause of the odor usually detected when phosphorus is exposed to the air. The red variety does not oxidize in the air, and may be handled with impunity. Phosphorus unites readily with fluorine, chlorine, bromine, and iodine, forming in each case two compounds of the general formula PR_3 and PR_5, except in the case of iodine, which forms PI_2 and PI_3. An oxychloride of phosphorus,

POCl, is also known. It combines with most other elements except-ing carbon and nitrogen. It reduces some metallic salts, as copper and silver, to the metallic state.

Tests.—Its phosphorescence in the dark, either as found or after separating it with carbon disulphide and evaporation of the latter liquid, is used as a test. It imparts a green color to the hydrogen flame, when this gas is conducted through a solution containing it before being burned.

Physiological Action.—Owing to the ready inflammability of the ordinary variety, deep burns are liable to occur from careless handling, which are more serious and difficult to heal than burns from other combustibles. When taken internally, phosphorus is a very poisonous substance. Cases of poisoning from " ratsbane " or " rat poison " containing it are not infrequent.

The symptoms of acute poisoning are a garlicky odor and taste in the mouth ; heat and burning in the stomach ; vomiting of a dark-colored matter, which is phosphorescent when shaken in the dark. Weak pulse, low temperature, cold extremities, dilated pupils, and a clear mind are usually seen. Death occurs in from two to twelve days. The average time is about three to four days.

These symptoms may make their appearance in an hour after the poison is taken, or after three or four days.

The poisonous dose varies ; $\frac{1}{50}$ to $\frac{1}{8}$ of a grain has produced death.

Antidotes.—There is no chemical antidote. Emetics or the stomach-pump are the best early treatment ; then, mucilaginous drinks, with lime or magnesia, or oil of turpentine,—the old oil is best,—but no other oils should be given, as they dissolve the phos-phorus and favor absorption. Recovery is rare.

Chronic poisoning of workmen in match-factories frequently occurs ; the symptoms are fatigue, pains in stomach and bowels, with diarrhea, carious teeth, swollen and inflamed gums, and finally necrosis of the jaws, usually the lower. Fatty degeneration of the liver, kidneys, heart, and other muscles, and destruction of the red corpuscles are also common.

These evils are now remedied by using **red phosphorus** in mak-ing matches, as it is not poisonous.

Official Preparations.—Oleum Phosphoratum (U. S. P., Br.).—A one per cent. solution of phosphorus in sweet-almond oil.

Pilulæ Phosphori (U. S. P.).—These pills contain 0.0006 gm. ($\frac{1}{100}$ gr.) of phosphorus each, and are coated with balsam of tolu.

Spiritus Phosphori (U. S. P.).—Spirit or tincture of phos-phorus. This is a solution of phosphorus in absolute alcohol, made by distillation, and containing 1.2 gm. in 1000 c.c.; it is used for

making **elixir phosphori** (U. S. P.). This elixir contains 210 c.c. of the tincture and 550 c.c. of glycerin to the liter.

Phosphorus and Hydrogen.—There are three hydrides of phosphorus known, which are all formed by boiling phosphorus with strong potash or soda-lye, or with milk of lime.

$$3NaOH + P_4 + 3H_2O = 3NaH_2PO_2 + PH_3.$$
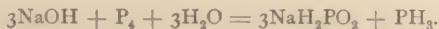
It is also produced by the action of water on calcium and other phosphides.

$$3Ca_3P_2 + 12H_2O = 6Ca(OH)_2 + 4PH_3 + 2P.$$

They appear as a gaseous mixture, which takes fire spontaneously on coming to the air. When the beak of the retort in which it is prepared dips under water, a precaution always to be taken, each bubble ignites on coming to the surface, producing beautiful white rings of P_2O_5. This inflammable gas, composed mostly of PH_3, is found, on examination, to contain also a liquid compound, P_2H_4, which is highly inflammable on exposure to air, while the gas PH_3 is not. This yellow volatile liquid, on standing in sunlight, deposits a yellow solid, P_4H_2.

Phosphin (**Phosphoretted Hydrogen**), PH_3, is a colorless gas, sparingly soluble in water, and has a strong alliaceous odor.

The impure gas is formed during the putrefactive decomposition of organic substances containing phosphorus, especially under water, and takes fire spontaneously on rising to the surface, producing the **ignis fatuus,** or '' Will o' the Wisp,'' sometimes seen in marshy places. The gas is very poisonous, even in small quantities. The blood, after deaths caused by it, is found to be dark-colored, with a violet tinge, and has lost the power of absorbing oxygen. It poisons by its reducing action on the blood. Its density is 17, and its sp. gr. 1.134.

Phosphin resembles, in chemical behavior, the corresponding compound of nitrogen, NH_3. It unites directly with HBr and HI to form **phosphonium bromide,** PH_4Br, **and iodide,** PH_4I, corresponding with the ammonium compounds, NH_4Br and NH_4I.

Phosphorus and the Halogens.—Phosphorus forms the following compounds with the halogen group:

$$PF_3, \quad PCl_3, \quad PBr_3, \quad PI_3.$$
$$PF_5, \quad PCl_5, \quad PBr_5, \quad P_2I_4.$$
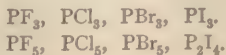
Phosphorus forms four compounds with chlorine. **Phosphorus trichloride,** PCl_3, is a colorless fuming liquid, boiling at 74° C.

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(165.2° F.), sp. gr. 1.64, and prepared by direct union of the elements. It is much used as a reagent in organic chemistry.

Phosphorus pentachloride, PCl_5, is a yellowish-white, crystalline solid, fuming in the air, and subliming without fusion when heated. It is prepared by treating PCl_3 with an excess of chlorine, and is used as a reagent in organic chemistry.

Phosphorus oxychloride, $POCl_3$, is formed by the action of a limited quantity of water on the pentachloride. It is a colorless liquid with a pungent odor and a sp. gr. of 1.7. Boils at 110° C. (230° F.). **Phosphorus thiochloride,** PSCl, is also known. Phosphorus unites directly with bromine, giving a tribromide, a pentabromide, an oxybromide, POBr, and a thiobromide, PSBr, and, with iodine, giving two crystalline solid compounds, PI_3 and P_2I_4; and, with fluorine, giving PF_3 and PF_5. These latter compounds, as well as those of phosphorus with sulphur, of which there are six known, are of no special interest to the medical student.

Phosphorus and Oxygen.—The following oxides and acids are known :

P_4O, Phosphorus monoxide. Hypophosphorous acid.
P_2O_3, $O = P — O — P = O$ Phosphorus trioxide + $3H_2O = 2H_3PO_3$. Phosphorous acid.

P_2O_4, $\begin{smallmatrix} O \\ O \end{smallmatrix}\!\!\searrow\!\! P—P \!\!\swarrow\!\!\begin{smallmatrix} O \\ O \end{smallmatrix}$ Phosphorus tetroxide.

P_2O_5, $\begin{smallmatrix} O \\ O \end{smallmatrix}\!\!\searrow\!\! P—O—P \!\!\swarrow\!\!\begin{smallmatrix} O \\ O \end{smallmatrix}$ Phosphorus pentoxide

$\begin{cases} + 3H_2O = 2H_3PO_4 \\ \text{Orthophosphoric acid.} \\ + 2H_2O = H_4P_2O_7 \\ \text{Pyrophosphoric acid.} \\ + H_2O = 2HPO_3 \\ \text{Metaphosphoric acid.} \end{cases}$
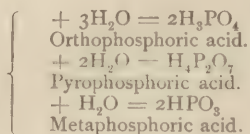
Phosphorous Oxide, Phosphorus Trioxide.—P_2O_3. This compound is formed by the slow oxidation of phosphorus in dry air. When dissolved in water it forms **phosphorous acid,** $\begin{smallmatrix} H—O— \\ H—O— \end{smallmatrix} P \begin{smallmatrix} O \\ —H \end{smallmatrix}$.

$$P_2O_3 + 3H_2O = 2H_3PO_3 \text{ or } 2H_2PHO_3.$$

Phosphorous acid is a colorless liquid, which is easily oxidized to phosphoric acid by absorbing oxygen from the air. It is a dibasic acid. Its salts are known as phosphites.

Na_2PHO_3 Sodium phosphite.
K_2PHO_3 Potassium phosphite.

Tests.—1. With $HgCl_2$ it gives a white ppt. consisting of Hg_2Cl_2.
2. With $AgNO_3$ it gives a black ppt. of metallic silver.

Phosphoric Oxide, Phosphorus Pentoxide.—P_2O_5. This is formed by the rapid burning of phosphorus in the air, and rises as a voluminous white cloud. It has a powerful affinity for water, with which it combines with a hissing noise, forming metaphosphoric acid ; this, when heated with more water, is converted into orthophosphoric acid.
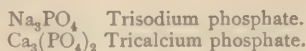
$$P_2O_5 + H_2O = 2HPO_3.$$
$$2HPO_3 + 2H_2O = 2H_3PO_4.$$
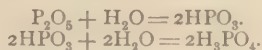
Orthophosphoric acid, or **common phosphoric acid,** H_3PO_4, is the most important acid of phosphorus. It is readily prepared by boiling phosphorus with diluted nitric acid and evaporating the solution to a syrupy consistency.

A very strong nitric acid should not be used, because the oxidation would then be so rapid that an explosion might occur.

$$3P_2 + 10HNO_3 + 4H_2O = 6H_3PO_4 + 5N_2O_2.$$

It may also be made by decomposing phosphates with sulphuric acid. It is a tribasic acid forming three series of salts, namely :

1. Normal salts.

Na_3PO_4 Trisodium phosphate.
$Ca_3(PO_4)_2$ Tricalcium phosphate.

2. Acid Salts.

A. $\begin{cases} Na_2HPO_3 & \text{Disodium-hydrogen phosphate.} \\ Ca_2H_2(PO_4)_2 & \text{Dicalcium-hydrogen phosphate.} \end{cases}$

B. $\begin{cases} NaH_2PO_4 & \text{Sodium-bihydrogen phosphate.} \\ CaH_4(PO_4)_2 & \text{Mono-calcium-tetrahydrogen phosphate.} \end{cases}$
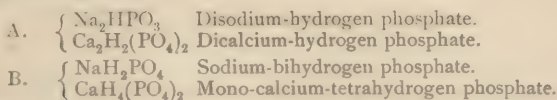
Those under A have a neutral, and those under B an acid reaction.

3. Double salts.

NH_4MgPO_4 Ammonium-magnesium phosphate.
$KBaPO_4$ Potassium-barium phosphate.
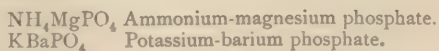
Acidum phosphoricum (U. S. P.) is a colorless, odorless, non-fuming, strongly acid liquid, containing not less than 85 per cent. of absolute orthophosphoric acid. Specific gravity, 1.71 at 15° C. (59° F.). It is miscible in all proportions with water and alcohol.

When heated to 200° C. (392° F.) it loses water, and is gradually converted into pyrophosphoric acid. At a higher temperature it is converted into metaphosphoric acid, which volatilizes in dense fumes and condenses into a transparent mass called **glacial phosphoric acid.**

$$2H_3PO_4 - H_2O = H_4P_2O_7 \quad \text{Pyrophosphoric acid.}$$
$$2H_3PO_4 - 2H_2O = 2HPO_3 \quad \text{Glacial or metaphosphoric acid.}$$
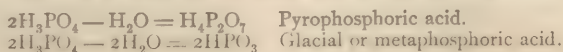
Acidum phosphoricum dilutum (U. S. P.) contains 10 per cent. of absolute H_3PO_4. Specific gravity is 1.057 at 15° C. (59° F.).

Tests.—1. Add a slight excess of NH_4OH, then a solution of NH_4Cl and some $MgSO_4$ solution. A white crystalline precipitate of ammonium-magnesium phosphate is produced.

$$H_3PO_4 + MgSO_4 + 3NH_4OH = NH_4MgPO_4 + (NH_4)_2SO_4 + 3H_2O.$$

2. If this ppt. be dissolved in dilute acetic acid and a solution of $AgNO_3$ added, a yellow ppt. of silver phosphate is produced.

3. If a solution of ammonium molybdate in dilute HNO_3 be added to phosphoric acid, or to a phosphate, and heat applied, a yellow ppt. of phosphomolybdate of ammonium is produced. The ppt. is readily soluble in ammonia water. This is a very delicate test.

Acidum phosphoricum concentratum and **acidum phosphoricum dilutum** (Br.) contain, respectively, 66.3 and 13.8 per cent. of absolute acid.

Pyrophosphoric Acid.—When phosphoric acid is heated to about 200° C. (392° F.), two molecules of the acid lose one molecule of water, and then unite to form a doubly condensed molecule, which is called pyrophosphoric acid. This is a tetrabasic acid, $H_4P_2O_7$, and forms salts called pyrophosphates. Sodium pyrophosphate has the formula $Na_4P_2O_7$.

Tests.—1. It gives a white ppt. with ammonio-nitrate of silver. The ortho-acid gives a yellow ppt.

2. It is not precipitated by ammonium molybdate, and does not coagulate albumin.

Metaphosphoric Acid, Glacial Phosphoric Acid.—HPO_3. When pyrophosphoric acid is heated almost to redness, metaphosphoric acid is produced as a white, glassy, colorless solid. It is usually prepared by heating ammonium phosphate to a red heat.

$$(NH_4)_3PO_4 = 3NH_3 + H_2O + HPO_3.$$

Metaphosphoric acid is monobasic, and forms salts called metaphosphates. $NaPO_3$ is the formula of metaphosphate of sodium.

Tests.—1. It gives a white precipitate with ammonio-nitrate of silver.

2. It coagulates albumin, while pyro- and orthophosphoric acids do not.

3. It is not precipitated by $MgSO_4$, in the presence of NH_4OH and NH_4Cl, as is the ortho-acid.

Meta- and pyrophosphoric acids and their salts, when taken internally, are said to have a decided inhibitory action upon the motor

ganglia of the heart, and may even cause sudden death when given in too large quantities.

Hypophosphorous Acid.—H_3PO_2. When ordinary phosphorus is boiled with a solution of sodium, potassium, barium, or calcium hydroxide, phosphorus hydride escapes, and there is formed in the solution a hypophosphite of the metal present. The acid may be prepared from the barium salt by treatment with enough dilute sulphuric acid to precipitate the barium as sulphate. The filtered solution is then to be concentrated under the air-pump, as heat decomposes it. The acid thus prepared is a colorless, syrupy, strongly acid liquid; it is unstable in the air, gradually changing into phosphorous and phosphoric acids. The acid is seldom prescribed, but several of its salts are used in medicine. They are administered in powder, pill, in solution in water with a little citric acid, or in the form of syrup. They have a strong reducing action on many metallic salts, and this should be remembered in prescribing them. **Mercuric chloride** is reduced to **metallic mercury** by the alkaline **hypophosphites,** and **ferric** to **ferrous salts.**

Acidum hypophosphorosum dilutum (U. S. P.) is a colorless, odorless liquid, miscible in all proportions with water. It should contain ten per cent. of absolute hypophosphorous acid, H_3PO_2 or HPH_2O_2.

When subjected to high temperatures it breaks up into PH_3 and H_3PO_4, the PH_3 igniting on contact with the air.

Tests.—1. Silver nitrate gives a black precipitate of metallic silver.

2. When gently heated with $CuSO_4$ solution, a yellow precipitate of hydride of copper falls, which rapidly turns reddish-brown.

Hypophosphorous as well as phosphorous acid is peculiar in its composition. While there are three atoms of hydrogen in the molecules of both acids, but one in the first and two in the second are basic—*i. e.*, that can be replaced by a basic radical or metallic atom. In these two acids the phosphorus is pentad, as in phosphoric acid. In hypophosphorous acid two non-basic hydrogen atoms are believed to be united directly to the phosphorus, while the basic hydrogen atom is linked to it by an oxygen atom, thus :
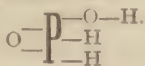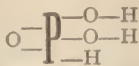
Hypophosphorous Acid.   Phosphorous Acid.   Phosphoric Acid.
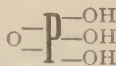
ARSENIC.

As = 75.

Occurrence.—Arsenic occurs native and as metallic arsenides, as the sulphides **orpiment** and **realgar,** and as arsenical pyrites or **mispickel.** Besides occurring in these minerals in considerable quantities, it is contained in small quantities in a great number of other minerals, and even in organic substances. The sulphides and the element were known to the ancients.

Preparation.—It is usually obtained in the form of the oxide by calcining mispickel and condensing the white volatilized As_2O_3; this oxide is then strongly heated in a retort with charcoal, when the element distils over. In some places it is distilled from arsenical pyrites in closed retorts, when the following reaction takes place :

$$FeS_2.As_2Fe = As_2 + 2FeS.$$
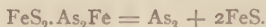
Although this is the method most used, it may be obtained from other minerals containing it.

Properties.—A brittle, steel-gray, crystalline solid, possessing a metallic luster and a sp. gr. of 5.75. It also exists as an amorphous, lusterless, black mass, easily pulverized, and having a sp. gr. of 4.71. When heated without contact with air, under ordinary pressures, it sublimes at 180° C. (356° F.) without previous fusion ; but under strong pressure it fuses. Its vapor has a yellow color and a density of 150 ; its molecular weight is, therefore, 300, and its molecular formula As_4. At a white heat its density is 75 and molecular formula As_2. In dry air it is permanent ; but when heated it burns with a bluish flame, emitting the odor of garlic and white fumes of arsenous oxide, As_2O_3. It combines directly with many of the elements, both metallic and non-metallic, as chlorine, bromine, iodine, copper, iron, etc., yielding arsenides. The metallic arsenides resemble alloys. It combines readily with **nascent hydrogen,** which takes it from any of its compounds. Nitric and sulphuric acids are decomposed by it, without forming salts. It is oxidized by boiling solutions of caustic potash, forming potassium arsenite and arsenide, and arsin.

Arsenic is used in pyrotechny, in the manufacture of fly-poison (under the name of cobalt), shot, and certain pigments.

Arsenic and Hydrogen.—But one arsenide of hydrogen is known, AsH_3.

Hydrogen arsenide, arseniuretted hydrogen, or **arsin,** AsH_3, is of great practical interest to the toxicologist, as it enters into some of the most delicate tests for the detection of the element.

It may be prepared by a number of reactions, the most common of which are the following:

1. By decomposing the metallic arsenides with hydrochloric acid.

2. By the action of nascent hydrogen upon arsenical compounds. This may be generated in the hot solution by the action of caustic potash or dilute sulphuric acid upon metallic zinc.

3. By the reducing action of moist organic matter upon compounds of arsenic.

It is a colorless gas, with a strong garlic odor, combustible in air, burning with a bluish-white flame, and emitting white fumes of As_2O_3; a cold surface pressed down upon this flame receives a black stain of arsenic. When passed through a tube heated to a dull red heat, it is decomposed into hydrogen and arsenic, which last deposits in the cooler part of the tube as a metallic mirror. (See Marsh's Test, p. 196.)

The gas is readily decomposed by oxidizing agents and the alkaline hydroxides. It is exceedingly poisonous.

Arsenic and the Halogen Elements.—Arsenic forms one compound with each of this group of elements, with the general formula AsR_3, in which R stands for a halogen atom.

The trifluoride and the trichloride are liquids, the first boiling at 63° C. (145.4° F.) and the second at 134° C. (273° F.). They are formed when a fluoride or chloride is heated with arsenic trioxide and sulphuric acid.

The tri-iodide and tribromide of arsenic are obtained by direct union of the elements. They are both solids. The tri-iodide, **arseni iodidum,** AsI_3, is official. It occurs as glossy, orange-red, crystalline masses or scales. It has an iodine-like odor, and gradually loses iodine upon exposure to light and air. It is soluble in about seven parts of water and in thirty parts of alcohol. The aqueous solution gradually decomposes into arsenous and hydriodic acids. It is used in the preparation of **liquor arseni et hydrargyri iodidi** (Donovan's solution) (U. S. P.). This solution contains one per cent. each of AsI_3 and HgI_2.

Oxides and Acids of Arsenic.—Arsenic forms two oxides, with corresponding acids:

As_2O_3	H_3AsO_3
Arsenous Oxide or Anhydride.	**Arsenous Acid.**
As_2O_5	H_3AsO_4
Arsenic Oxide or Anhydride.	**Arsenic Acid.**

Arsenous oxide, acidum arsenosum (U. S. P., Br.), As_2O_3, is the most important of the compounds of arsenic. It occurs in

nature as arsenic "bloom." It is obtained artificially as a side-product in roasting ores of other metals containing arsenic, when it volatilizes and is condensed in large chambers as a white powder. It is purified by resublimation in iron retorts, and is obtained in the form of a white powder or glassy-looking solid, of a sp. gr. of 3.69.

Properties.—As ordinarily met with, "white arsenic" is a white, somewhat gritty powder, which under the microscope is seen to be made up of more or less regular octahedral crystals. When the vapor is rapidly cooled, the crystals take the form of rhombic prisms, and it is, therefore, **dimorphous.** When heated, it sublimes without fusing at about 218° C. (424° F.). When heated in sealed tubes, it melts into a vitreous mass. The density of the vapor is 198, corresponding to the formula As_4O_6, which is probably the formula of the vitreous variety, while that of the octahedral variety is As_2O_3. It is soluble with difficulty in water, forming a sweetish, metallic, and nauseous-tasting poisonous solution of arsenous acid ($q. v.$). It enters into combination with hydrochloric acid and alkaline hydroxides, the arsenic atoms playing the basic rôle in the former and the acid rôle in the latter. Nascent hydrogen reduces the oxide and converts it into arsin, AsH_3, while oxidizing agents convert it into arsenic acid.

Arsenous acid, H_3AsO_3, is formed by dissolving As_2O_3 in water. A solution of the acid in dilute hydrochloric acid is official under the name of **liquor acidi arsenosi** (U. S. P.), **liquor arsenici hydrochloricus** (Br.), containing one per cent. of As_2O_3. It forms a series of salts called arsenites. **Potassium arsenite** is official as **Fowler's solution,** or **liq. potass. arsenitis** (U. S. P.), **liq. arsenicalis** (Br.).

Scheele's green is an arsenite of copper, used as a pigment. **Paris green** is a mixture of acetate and arsenite of copper.

Arsenic oxide, As_2O_5, is a white, amorphous, deliquescent solid, dissolving in water to produce **arsenic acid.**

$$As_2O_5 + 3H_2O = 2H_3AsO_4.$$
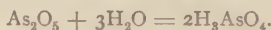
Arsenic acid is usually prepared by warming arsenous acid with nitric acid, when the As_2O_3 is oxidized at the expense of the nitric acid. On evaporating, the solution yields needle-shaped crystals of H_3AsO_4. The aqueous solution is strongly acid. On heating the crystals of arsenic acid, both the pyro-arsenic and meta-arsenic acids are produced, corresponding to the similar acids of phosphorus. But one salt of this acid is official, **sodium arsenate,** $Na_2HAsO_4.7H_2O$; also a one per cent. solution of this salt, **liquor sodii arsenatis** (U. S. P., Br.).

Arsenic and Sulphur.—There are at least three well-known compounds of arsenic and sulphur, As_2S_3, As_2S_5, and As_2S_2.

Arsenous sulphide, As_2S_3, occurs native as **orpiment**, in the form of golden-yellow, crystalline masses. It may be prepared artificially by precipitating arsenous acid or its salts with hydric sulphide, or by heating together sulphur and arsenous oxide, As_2O_3. It is lemon-yellow in color, soluble in the alkaline hydroxides and in yellow ammonium sulphide, but insoluble in water and dilute acids. It may be regarded as an anhydride of thio-arsenous acid, as it forms thio-arsenites with alkaline hydroxides.

$$As_2S_3 + 4KOH = HK_2AsO_3 + HK_2AsS_3 + H_2O.$$

Arsenic pentasulphide, As_2S_5, is also a bright yellow powder, but is of no special interest.

Arsenic disulphide, As_2S_2, occurs native, as **realgar**, in the form of orange-red, crystalline masses of sp. gr. 3.5. Realgar and orpiment are used as pigments.

Arsenic Poisoning.—**Toxicology.**—From the earliest history of arsenic, it has been used as a poison for criminal purposes.

While every physician should not undertake the analysis in cases of suspected poisoning by this agent, a knowledge of the outlines of the chemist's methods of analysis, etc., will teach the physician to prepare the way for him. Moreover, a few preliminary tests by the physician may frequently save much unnecessary litigation and expense in suspected cases. Other reasons might be given why every physician should have some knowledge of toxicological science, that care may be taken to punish the guilty and protect the innocent. The attending physician is often responsible for the connection of the links of evidence. All compounds of arsenic are poisonous, and the poison usually enters the system by the mouth, although it has been absorbed by the skin, mucous membranes, or abraded surfaces in sufficient quantities to produce poisonous results, especially chronic poisoning.

Colored wall-paper, colored toys, confectionery, and certain anilin dyes used in fabrics may give rise to accidental poisoning.

The physician's duty in cases of poisoning may be briefly stated as follows: In case foul play is suspected, he should not fail to make careful notes, at the time, as to dates, symptoms, and circumstances, or facts leading to suspicion.

The physician should collect and preserve the urine, feces, vomit, and the suspected vehicle of the poison, and place them under seal, or lock and key. He should test some one or all of these, to satisfy himself as to the truth or falsity of his suspicion. As little publicity

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as possible should be given to matters of fact or of opinion at the time. He should not be too ready to express an opinion upon the origin of the poison, in cases of this kind, lest he jeopardize the reputation of his patient or others. Whether a fatal termination is expected or not, it is wise to take these precautions.

In case of fatal termination, he should notify the prosecuting officer or coroner of his suspicion, and immediately request an autopsy ; but he is not released from responsibility in the case by so doing, nor at liberty to tell all he knows, until summoned to do so on the witness-stand.

Before attending the autopsy the physician should carefully refresh his memory upon the directions for making postmortem examinations, and on the postmortem appearances in cases of poisoning, whether he is to make the examination himself or not. If possible, the chemist who is to make the analysis should be present at the autopsy. (See Woodman and Tidy, '' Forensic Medicine.'') The entire intestinal canal, at least one-half of the liver, the spleen, one kidney, the brain, and any urine remaining in the bladder should be saved. The entire intestinal canal, ligatured at both ends of the stomach and left unopened, is to be preserved in one jar, while the other organs may be placed in another jar. These jars must be new and clean, and closed with new corks or glass—not with metal caps. They are then to be closed with a seal, with some peculiar stamp upon it, so that they can not be opened without detection. They must not be intrusted to a servant or any irresponsible person, but turned over as soon as possible to the chemist, to the prosecuting officer, or to the coroner. Notes to be admitted on the witness-stand must be the original ; not a copy of those taken at the time to which they refer.

Symptoms of Arsenical Poisoning.—The symptoms are those of an intense irritant. There is usually marked burning pain in the epigastrium, increased by pressure. Violent vomiting, tenesmus, burning pains at the anus, and painful cramps in the legs are usually present. Intense thirst, dry, hot skin, severe headache, small, rapid pulse, anxious, pinched countenance, the eyes suffused and smarting, tongue dry and furred, photophobia, great restlessness, nervous twitchings, with a perfectly clear mind, are symptoms usually to be expected. The urine is diminished, with frequent and painful micturition. These symptoms may end in tetanic convulsions, collapse, or coma and death. Minimum fatal dose, from 1.5 to 2.5 grs. Chronic arsenical poisoning is usually attended by conjunctival inflammation and irritation of the skin, with a vesicular or nettle-rash eruption similar to that of scarlet fever. Irritation of the stomach and bowels,

exfoliation of the cuticle of the skin and tongue, and falling of the hair have been noticed. Local paralyses, preceded by numbness or tingling of the toes and fingers, and marked nervous disorders are of common occurrence.

Treatment.—Remove any unabsorbed poison from the stomach by emetics or with the stomach-pump, or, better, by thorough irrigation with the stomach-tube.

The best **antidote** is freshly precipitated ferric or magnesium hydroxide or a solution of **dialyzed iron.** The solution of **dialyzed iron,** now found in the shops, may be used instead of the above, and may be given in teaspoonful doses at short intervals. This forms an insoluble compound with the arsenous acid, and thus prevents further absorption.

There are two official antidotes : 1. **Freshly prepared ferric hydroxide.** This is made by adding ammonia water to a solution of ferric sulphate, thoroughly washing the precipitate with water to remove the ammonia, which is a strong caustic, and suspending the precipitate in water.

2. **Ferri oxidum hydratum cum magnesiæ.** It is directed that a solution of ferric sulphate and a mixture of magnesia and water be kept on hand, and, when wanted, the two poured together and shaken up. Ferric hydroxide and magnesium sulphate are formed. This mixture has the advantage of being free from ammonia, while the presence of magnesium sulphate is an additional advantage.

The symptoms caused by the absorbed poison are to be treated as they arise.

Toxicology.—There have been devised a large number of tests for the detection and identification of arsenic. Some of these are easy of application, while others will be used only by the chemist. We can only give the outline of these tests and leave the student to consult special works for details. The analysis after death, in cases of suspected poisoning, should not be undertaken by the physician, pharmacist, nor even by a chemist, unless he has a well-equipped laboratory, in which he can conduct the analysis from beginning to end, alone, and without interruption. During the life of the patient the physician should be able to test the urine. feces, suspected articles of diet, medicines, etc., for the presence or absence of arsenic. For this purpose he may use Reinsch's or Marsh's test, but it must be understood that neither of these tests alone, when performed as about to be described, is to be relied upon as positively certain.

Reinsch's test may be conducted as follows :

To a portion of the urine or other suspected liquid add about one-sixth its volume of pure hydrochloric acid and some strips of pure copper-foil and boil the solution. If arsenic be present, a steel-gray or bluish deposit will be formed on the surface of the copper. This

deposit is not positive proof of arsenic, however, as antimony, bismuth, and mercury may give similar deposits; it is necessary to apply tests to this deposit in order to determine its identity.   For this purpose the copper is removed, washed in water, dried between folds of filter-paper, and placed in a clean, dry, wide test-tube and heated to a dull red heat, taking care to heat only that portion of the tube containing the copper.   The tube may then be broken and the inner side of the fragments examined with a microscope for octahedral crystals of arsenous oxide.   The copper and the acid used must be shown to give no stain on prolonged boiling with distilled water.   This blank experiment must always be performed.

Marsh's test may be conducted as follows: Although the indications afforded by it are not conclusive in the presence of organic
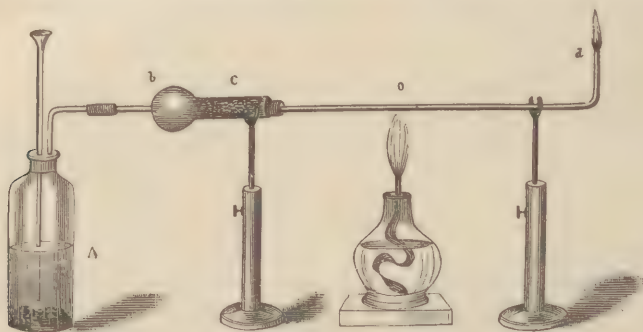
FIG. 56.

matters, it should always be used to confirm Reinsch's test. Into a bottle A, holding about 150 c.c. (f℥v), introduce some pieces of zinc, free from arsenic and antimony; then pour over these some water acidulated with sulphuric acid; close the flask with a cork containing a funnel tube and a delivery tube drawn to a fine point.   It is best to introduce a bulb-tube containing a pledget of cotton arranged as at c, figure 56.   After allowing the generation of hydrogen to go on for a considerable time, to expel the air from the upper part of the flask,—say, half an hour,—light the gas at the open end of the delivery tube d, and press a cold porcelain surface down upon the flame.   If the materials used are free from arsenic and antimony, there will be no black stain produced on the porcelain.

Having determined that the apparatus and materials are free from arsenic, put out the flame and pour the suspected fluid through the

funnel tube so as to admit little or no air with it into the flask.   Now ignite the gas and test the flame again with the cold porcelain surface. A brilliant black or brown stain, soluble in a solution of chlorinated soda, is probably arsenic.   Moisten one of these spots with nitric acid, when it should disappear ; evaporate the acid over a lamp, moisten the spot with water, and hold the dish over a vessel containing sul- phuretted hydrogen prepared by the action of sulphuric or hydrochloric acid upon sodium or potassium sulphide.   If the stain was due to arsenic the spot will turn lemon-yellow.   The antimony mirror is insoluble in chlorinated soda (Labarraque's solution), and after treatment as above gives an orange stain.   Now soften the glass, bend the delivery tube downward, and let it dip into a solution of $AgNO_3$; after an hour pour some very weak solution of NH_4OH upon the surface of the $AgNO_3$ solution.   A yellow precipitate at the line of separation of the two liquids shows the presence of arsenic.   If the substance to be tested is a solid, a small portion of it may be thrown upon a glowing charcoal, when arsenic, if present, will give an odor resembling garlic.   These tests will be sufficient to enable the physician to decide upon the pres- ence of arsenic during the life of the patient, and guide him in his treatment and behavior.

Fleitmann's Test.—Heat to boiling in a test-tube a strong solu- tion of potassium hydroxide in which some pieces of zinc or aluminum have been placed.   Add a drop or two of the suspected solution, spread a cap of filtering paper over the mouth of the tube, and moisten it with a little nitrate of silver solution.   A brown or black stain of metallic silver will appear upon the paper if arsenic is present.   The arsenous oxide is decomposed, the nascent hydrogen combines with the arsenic and forms arsin, AsH_3, which reacts with the silver nitrate, reducing it to metallic silver.   This test is very valuable, enabling the analyst to distinguish between arsenic and antimony, which latter does not give this reaction.

Sulphuretted hydrogen, H_2S, passed into an acidulated solution con- taining arsenous acid, throws down a lemon-yellow precipitate, con- sisting of As_2S_3, which dissolves in ammonia water and is reprecipi- tated by acids.

If solid arsenous oxide is mixed with some powdered charcoal and dry potassium carbonate, and placed in the bottom of a very narrow test-tube, or, better, a glass tube drawn out and having a bulb at one end (Fig. 57), and heated, the arsenous oxide is reduced, and metallic arsenic is deposited in the form of a ring on the cooler part of the tube.

The lower part of the tube may now be broken off and the arsenic mirror heated ; there being free access of air, the arsenic is oxidized

and deposited in the upper part of the tube, in the form of octahedral crystals of arsenous oxide.

Ammonionitrate of silver gives a lemon-yellow precipitate, with arsenous acid solutions, of arsenite of silver, Ag_3AsO_3. It gives a brown precipitate, Ag_3AsO_4, with arsenic acid.

Ammoniosulphate of copper gives a grass-green precipitate of arsenite of copper, also called Scheele's green, $CuHAsO_3$, with solutions of arsenous acid.

Bettendorff's Test.—Add a freshly prepared solution of stannous chloride to any arsenic compound, dissolved in strong hydrochloric acid, place in the mixture a small piece of tin-foil, and apply heat ; a brown color or grayish-brown precipitate is formed, according to the amount of arsenic present.

Gutzeit's Test.—Place in a test-tube about 1 gm. of pure zinc and add about 5 c.c. of diluted (about 6 per cent.) sulphuric acid ; then add about 1 c.c. of the solution to be tested, which should not be alkaline. Now fix a plug of cotton, moistened with lead acetate solution, in the test-tube not far from the top, and fasten over the mouth of the tube a cap made of three thicknesses of filter-paper, and

FIG. 57.

apply a drop or two of strong solution of silver nitrate to the upper one, and place the tube in a dark box and allow it to remain for some time. If arsenic is present in the solution, a bright yellow stain will appear upon the filter-paper, which upon the addition of water becomes black or brown. Antimony, when subjected to the above test, gives a dark color at once, without showing a previous yellow color. The zinc and the sulphuric acid should be tested before applying the above, to make sure that they contain no arsenic.

The chemist who undertakes the analysis, in cases of supposed poisoning, has no easy task. He must not confine his tests to any one poison. Poisons are generally divided into two groups, **inorganic** and **organic**. The limits of this work will not allow us to describe the details of procedure for the chemist, who will consult special works on toxicology.

In searching for mineral poisons, the organic matters must first be destroyed or separated by dialysis. For the latter process, see page 80.

For the destruction of organic matter, two methods may be used. The solid matters—the stomach and other organs—are to be cut in small pieces and placed in a new porcelain dish, mixed with hydro-

chloric acid, and heated over a water-bath. Small quantities of pure potassium chlorate are put in, from time to time, and stirred until the organic matter is destroyed. Or, sulphuric and nitric acids are used to thoroughly char the organic matter, and the whole diluted with water and filtered. The metals, except lead and barium, pass into the filtrate, and can be detected by either of the methods given above, or by other methods. These solutions may be evaporated to expel chlorine, or HNO_3, and treated with hydrosulphuric acid gas from twenty-four to forty-eight hours, when copper, lead, bismuth, and mercury give black or brown precipitates; arsenic, cadmium, and sometimes tin give a yellow and antimony an orange precipitate. In searching for arsenic, the yellow precipitate obtained is separated from the liquid by filtration. A portion of this is to be preserved in a sealed glass tube. The remainder is oxidized with nitric acid, fused with sodium carbonate and nitrate, and the sodium arsenate thus formed made to yield silver and copper arsenates; the former a reddish-brown and the latter a green precipitate. Other portions are converted into the octahedral crystals of trioxide, into the metallic state, etc., the object being to present the poison in court in as many different states as possible, so as to avoid the possibility of doubt in the minds of the jury. If the yellow sulphide (soluble in ammonia), the black metal (so called), the octahedral crystals, the mirrors with the above-mentioned properties, the coated copper obtained by Reinsch's test, the black deposit from silver nitrate, with arsenite in the filtrate, from Marsh's test, the arsenite and arsenate of silver, and arsenite of copper, etc., etc., are obtained with proper precautions, there is no room for doubt that the substance is really arsenic.

For further directions on this subject, the student is referred to Taylor on "Poisons," or Woodman and Tidy on "Forensic Medicine and Toxicology," or some other similar work.

ANTIMONY.

(STIBIUM.)

$$Sb = 119.6$$

Specific Gravity, 6.71.   Melting Point, 450° C. (842° F.).

Occurrence and Preparation.—Antimony occurs native; but the principal source is the trisulphide, Sb_2S_3, called **stibnite.** It occurs in a number of other ores as sulphide or oxide.

The element is easily obtained by roasting the sulphide and then fusing the oxide thus obtained with charcoal.

Properties.—Antimony is a bluish-white, brittle, crystalline solid,

isomorphous with arsenic, and resembling zinc in color and luster.
It tarnishes with difficulty, but takes fire at a red heat. It unites
readily with chlorine, forming two chlorides, $SbCl_3$ and $SbCl_5$, both
of which are decomposed by an excess of water. In physical
properties it resembles the metals, with which it forms alloys. In
chemical properties it plays both the positive and negative rôles with
facility. It is used as a constituent of type-metal, Babbitt's anti-
friction metal, Britannia, etc., to give hardness and to cause them to
expand in cooling and completely fill the molds.

An **amorphous variety** of the element has been obtained by
electrolysis of a solution of tartar emetic in antimony trichloride.
It resembles graphite in appearance.

Hydrogen Antimonide, Stibin, Antimoniuretted Hydrogen.
—SbH_3. A colorless, odorless gas, formed under the same conditions
as the corresponding compound of arsenic—*i. e.*, by nascent hydrogen
on reducible antimony compounds. It differs from that compound
in being much less poisonous, and giving a different reaction with
solutions of silver nitrate, as shown in the following equations :

$$6AgNO_3 + AsH_3 + 3H_2O = 6HNO_3 + H_3AsO_3 + 3Ag_2$$
$$3AgNO_3 + SbH_3 = 3HNO_3 + SbAg_3$$

<div style="text-align:center">Silver   Metallic
Antimonide.   Silver.</div>
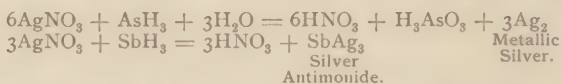
By carefully floating a solution of ammonium hydroxide over the
silver nitrate solution, after passing the gas through it for some time,
a yellow precipitate of arsenite of silver will be formed at the line of
separation of the two liquids, while, in the case of antimony, no
such precipitate will be formed. This gas is formed in Marsh's
apparatus when antimony is present, and it is likely to be confounded
with arsenic unless very great pains be taken to avoid it.

The mirrors obtained on the porcelain, or in the delivery tube,
require a higher temperature to volatilize them in the case of anti-
mony; they are difficultly soluble in hypochlorite solution, are
sooty and less brilliant in appearance, there is no garlic odor, and by
oxidation they do not form crystals.

Chlorides, Bromides, and Iodides.—Two chlorides and two
oxychlorides exist.

Antimony chloride,—antimony trichloride or **antimony
protochloride,—butter of antimony,** $SbCl_3$, may be obtained by
dissolving the trisulphide in hydrochloric acid.

$$Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S.$$
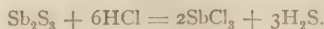
At low temperatures it is a crystalline solid, and melts at 73.2° C.
(164° F.) to a yellow, oily liquid. A solution of sp. gr. 1.47 is

sometimes used as an escharotic. On the addition of considerable water, this chloride is decomposed into the **oxychloride**, SbOCl, formerly called **powder of algaroth.** $SbCl_3$ is poisonous, acting both locally and as a true poison.

Antimony pentachloride, $SbCl_5$, is a fuming, colorless liquid, of little interest to the medical student. The iodides, bromides, and fluorides are similar to the trichloride in composition and properties. The iodide has been used in medicine.

Sulphides of Antimony.—Two sulphides and several oxysulphides are known. **Antimony trisulphide, sulphuret of antimony, black antimony, antimonii sulphidum** (U. S. P.), **antimonium nigrum** (Br.), Sb_2S_3, occurs native as a steel-gray, crystalline solid. Artificially, it may be prepared as an orange-colored powder, by precipitating a soluble antimony salt with hydrogen sulphide. When the native ore is roasted in the air it is partially decomposed, and fuses into a vitreous, somewhat transparent mass, known as **glass of antimony,** or **crocus.**

Antimonii sulphidum purificatum (U. S. P., Br.) is made by reducing sulphide of antimony to a very fine powder, and then macerating with ammonia water for five days, and finally washing with water and drying. It is a grayish-black powder, having no luster, and being without odor or taste.

Antimonium sulphuratum (U. S. P., Br.) is a reddish-brown powder prepared by dissolving the native sulphide in a solution of sodium hydroxide and reprecipitating the hot solution with sulphuric acid. It contains a little antimonous oxide, Sb_2O_3, but is mostly Sb_2S_3, and is used mostly in pill form. Dose, gr. ij to gr. xx. Plummer's pill, **pil. antimonii comp.,** contains this sulphide with calomel. **Kermes' mineral** is another name for sulphurated antimony.

By treating a hot solution of the trisulphide with sodium thiosulphate a fine red precipitate of oxysulphide is obtained, which is used as a pigment under the name of **antimony vermilion.**

Antimonic sulphide, or **antimony pentasulphide,** Sb_2S_5, is best obtained by decomposing sulphantimonates with a dilute acid. It is an orange-red or brown powder, readily soluble in alkalies and alkaline sulphides, forming antimonates and sulphantimonates, with the general formula $M_3'SbO_4$ and $MSbS_4$, in which M stands for a metallic atom. Sulphantimonates of silver, lead, and iron occur as minerals.

Oxides and Acids of Antimony.—Three oxides are known:

Antimony trioxide,	Sb_2O_3, Metantimonic acid, $HSbO_2$.
" pentoxide,	Sb_2O_5.
" tetroxide,	Sb_2O_4 or $SbOSbO_3$.

Antimony trioxide, antimonii oxidum (U. S. P., Br.), Sb_2O_3, is obtained by roasting the metal in air or by treating it with HNO_3 and evaporating the excess of acid. It is a white, amorphous powder capable of being sublimed. It is insoluble in water, alcohol, or nitric acid.

Metantimonic acid, $HSbO_2$, is obtained as a white precipitate by adding a solution of sodium carbonate to a solution of $SbCl_3$.

$$2SbCl_3 + 3Na_2CO_3 + H_2O = 2HSbO_2 + 6NaCl + 3CO_2.$$

By boiling, this acid is changed into the trioxide. Antimony reacts with both acids and alkalies to form salts. Thus, we have $NaSbO_2$, $SbO(NO_3)$, and $Sb(NO_3)_3$. We also have **antimony sulphate,** $Sb_2(SO_4)_3$, and **antimonyl sulphate,** $(SbO)_2(SO_4)$, the former obtained by dissolving the oxide in strong and the latter in dilute sulphuric acid. Both are decomposed by excess of water.

Antimonic acid, H_3SbO_4, is obtained, as a white powder, insoluble in water and nitric acid, by treating antimony with warm concentrated HNO_3. Antimonous acid is first produced, but on standing in contact with excess of acid, it is converted into metantimonic acid.

$$Sb_2 + 4HNO_3 = 2HSbO_2 + 3NO_2 + NO + H_2O.$$
$$2HNO_3 + HSbO_2 = H_3SbO_4 + 2NO_2.$$
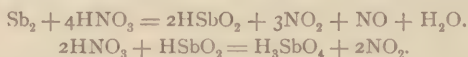
There are no salts of antimonic acid.

Pyroantimonic acid, $H_4Sb_2O_7$, is also known and may be obtained by treating its salts with hydrochloric acid.

By gently heating either of the above acids, antimony pentoxide is obtained as a yellow, amorphous mass, and by a stronger heat, with free access of air, it is converted into tetroxide, Sb_2O_4, which is usually regarded as an antimonite of antimonyl, $SbOSbO_3$. It is a white, non-volatile powder, becoming yellow when heated.

Potassium antimonyl tartrate, tartar emetic, antimonii et potassii tartras, antimonium tartaratum (Br.), $K(SbO)$-$C_4H_4O_6.H_2O$, is one of the most commonly employed compounds of antimony.

It is prepared by boiling 3 parts of Sb_2O_3 with 4 parts of cream of tartar, $KHC_4H_4O_6$, in water for an hour, filtering, evaporating the filtrate, and allowing it to crystallize out. It occurs in small, transparent, rhombic crystals, which effloresce in air and have a sweetish, afterward disagreeable, metallic taste and an acid reaction. Soluble in 17 parts of water at 15° C. (59° F.) and 3 parts boiling water, and insoluble in alcohol. Its solutions are incompatible with alcohol, hydrochloric acid, and alkaline carbonates. Free tartaric acid pre-

vents the precipitation by the above reagents. On being heated to redness it chars.

It is used in medicine, and enters into the composition of **syr. scillæ compositus** and **vinum antimonii.** The dose of tartar emetic is gr. j–ij (0.065–0.125 gm.), as an emetic; as an expectorant, gr. $\frac{1}{16}$ to gr. $\frac{1}{4}$ (0.004–0.016 gm.); of the wine, 10 to 30 drops.

Physiological Action.—Locally, the soluble compounds of antimony act as powerful irritants. Tartar emetic causes a pustular eruption resembling variola, which is accompanied with fever and systemic disturbances. Cases of poisoning from antimony used as a mordant in dyeing clothing have been reported. Internally, tartar emetic is employed as an expectorant, sudorific, sedative, nauseant, and emetic, according to the dose used. In full doses it causes vomiting, purging, and griping pains, with great depression. In excessive quantity it acts as an irritant poison and has produced death by syncope, preceded by convulsions and delirium. One and a half grains (0.092 gm.) have produced death, but recovery has occurred after very large doses because of the rejection of the poison by vomiting.

The treatment should consist in promoting free vomiting or removal of the poison with the stomach-pump. The proper antidote is tannin, which forms an insoluble compound with antimony; it may be administered in the form of infusion of tea, oak bark, nut-galls, etc. Stimulants are then to be administered.

In suspected cases examine the urine or viscera by Marsh's test (p. 196). Soluble salts of antimony give an orange-colored precipitate with H_2S, in acid solutions, which is soluble in yellow ammonium sulphide and in strong hydrochloric acid. In Reinsch's test a bluish stain is obtained, but the sublimate obtained from it is amorphous, not crystalline. (See p. 195.)

BISMUTH.

$$Bi = 207 \ (206.54, H = 1).$$

Occurrence and Preparation.—Occurs native and as a sulphide —bismuthite. The element is obtained by roasting the sulphide in air and reducing the resulting oxide with charcoal, iron being added to take up the remaining sulphur.

Properties.—Bismuth is a white, metallic-looking solid with a bronze tint. Specific gravity, 9.9. It is brittle and crystallizes in rhombohedrons; fuses at 267° C. (512.5° F.), volatilizes at a white heat, and if heated in air it burns to Bi_2O_3. HNO_3 and hot H_2SO_4 dissolve it, but HCl does not. Water precipitates basic salts from the

solutions of the neutral salts. It alloys with the metals, and is sometimes described as a metal.

Bismuth chloride, $BiCl_3$, may be obtained by treating the element with chlorine or aqua regia. It is a soft, white, deliquescent, volatile solid. Water, added to its solutions, precipitates the white **oxychloride.**

$$BiCl_3 + H_2O = BiOCl + 2HCl.$$
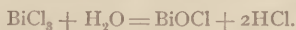
This reaction resembles that of $SbCl_3$. BiOCl, as well as the subnitrate, is sold as pearl powder, or pearl white, and is used as a cosmetic. They are blackened by H_2S. The compounds Bi_2Br_4 and BiI_3 are similar to Bi_2Cl_4 and $BiCl_3$. Bismuth does not form a hydride, BiH_3, as does the rest of the group.

Oxygen Compounds.—Four oxides of bismuth are known, namely: Bismuth dioxide, Bi_2O_2; bismuth trioxide, Bi_2O_3; bismuth tetroxide, Bi_2O_4; bismuth pentoxide, Bi_2O_5. Bismuth oxide, Bi_2O_3, **bismuthi oxidum** (Br.), is a yellow powder, insoluble in water and alkalies; it may be prepared by roasting bismuth or heating the nitrate or carbonate. When chlorine is passed through a solution of potassium hydroxide in which Bi_2O_3 is suspended, **bismuthic acid,** $HBiO_3$, is precipitated as a red powder. On gently heating this, the pentoxide, or **bismuthic oxide,** Bi_2O_5, is formed. Bismuth hydroxide, BiO_3H_3, is precipitated by a solution of NH_4OH from solutions of a bismuth salt. The metahydroxide, BiO_2H, is precipitated when caustic soda or potassa is added to a bismuth solution or to the nitrate suspended in water. This oxide is the one first precipitated in testing for sugar in Böttger's test.

Bismuth nitrate, $Bi(NO_3)_3$, is formed by dissolving bismuth, or the basic nitrate, in nitric acid and evaporating, when it crystallizes in large transparent prisms, $Bi(NO_3)_3.5H_2O$. It is soluble in a little water, but is decomposed by a large amount into a basic nitrate or subnitrate. The reaction varies with the amount of water used.

$$Bi\begin{matrix}-NO_3\\-NO_3\\-NO_3\end{matrix} + 2H_2O = Bi\begin{matrix}-NO_3\\-OH\\-OH\end{matrix} + 2HNO_3, \text{ or}$$

$$Bi\begin{matrix}-NO_3\\-NO_3\\-NO_3\end{matrix} + H_2O = Bi\begin{matrix}-NO_3\\-NO_3\\-OH\end{matrix} + HNO_3, \text{ or}$$

$$Bi\begin{matrix}-NO_3\\-NO_3\\-NO_3\end{matrix} + H_2O = Bi\begin{matrix}-O\\-NO_3\end{matrix} + 2HNO_3.$$
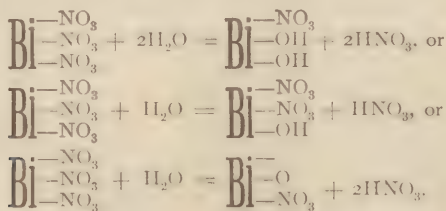
Bismuthi Subnitras (U. S. P., Br.).—As will be seen, the subnitrate of bismuth is not a definite and fixed compound, but a mixture.

It is a white powder, insoluble in water, but soluble in nitric acid. As arsenic and bismuth frequently occur together, the latter is apt to be contaminated by the former. Should unpleasant effects arise from its use, it should be tested with one of the tests described under Arsenic (*q. v.*). It is used internally and as a dressing for wounds.

A solution of two parts $BiONO_3$ and four parts $KNaC_4H_4O_6$ in 100 c.c. of a strong solution of sodium hydroxide is used as a delicate test for diabetic sugar. It becomes black on boiling, in the presence of glucose, from reduction of the bismuth.

Bismuth subcarbonate, bismuthi subcarbonas (U. S. P.),

bismuthi carbonas (Br.), $Bi\begin{cases} CO_3 \\ O \\ Bi-OH \\ OH \end{cases}$, is a light, white, odorless, and

tasteless powder, insoluble in water, and formed by the action of alkaline carbonates upon solutions of bismuth. Heat decomposes it into Bi_2O_3, H_2O, and carbon dioxide.

Bismuth sulphate, $Bi_2(SO_4)_3$, is formed by dissolving bismuth in sulphuric acid. It is of no special interest to physicians.

Bismuth citrate, bismuthi citras (U. S. P., Br.), $BiC_6H_5O_7$, is a white, amorphous, odorless, and tasteless powder, insoluble in water or alcohol, but soluble in ammonium hydroxide. Prepared by boiling the subnitrate in a solution of citric acid and precipitating the citrate with water. By dissolving the citrate in diluted ammonia water, and cautiously evaporating to a syrup and spreading on glass, shining pearly or translucent scales of **bismuth et ammonii citras** are obtained, soluble in water.

Bismuth subgallate, dermatol, $Bi(OH)_2C_6H_2(OH)_3CO_2$, is a saffron yellow, odorless, tasteless powder, insoluble in water, alcohol, or ether. It is prepared by mixing, with constant stirring, a warm solution of 1 part of gallic acid in 50 parts of water, with a solution of 3 parts of bismuth nitrate in 50 parts of water and 6 parts of glacial acetic acid. It is used as an intestinal antiseptic, and as a substitute for iodoform for external use. The other salts of bismuth used in medicine are the benzoate, salicylate, naphtolate, oleate, phenolate, pyrogallate, tribromphenolate, and a number of others.

Physiological Action. — The bismuth salts in medicinal doses are tonic, antispasmodic, mildly astringent, and antifermentative. They are used to allay gastro-intestinal irritation and diarrhea. When administered in considerable quantities, they produce black stools, from the presence of the sulphide formed by the H_2S of the intestines. In many cases of excessive diarrhea, with acid fermentation in the

stomach and intestines, this blackening does not occur, and its appearance marks an improvement in the case.

Cases of poisoning by large doses of the salts of bismuth are generally, if not always, due to the presence of arsenic in them.

Tests.—Water precipitates bismuth from its solutions, in the absence of much free mineral acid. Hydrogen sulphide and ammonium sulphide give a black precipitate, insoluble in water, dilute acids, and alkaline sulphides. **Potassium, sodium, and ammonium hydroxides** give a white precipitate, insoluble in excess of these reagents. Infusion of nut-galls gives an orange precipitate. **Potassium iodide** gives a brown precipitate, soluble in excess of reagent. When a drop of a solution containing bismuth is dropped on a piece of paper dipped in a solution of potassium sulphocyanate and dried, it forms a yellow spot.

GROUP IV.

Carbon,	$C =$	12.*
Silicon,	$Si =$	28.
Germanium,	$Ge =$	72.
Tin (Stannum),	$Sn =$	118.
Lead (Plumbum),	$Pb =$	207.

CARBON.

$C = 12$ (11.92) $(H = 1)$.

Occurrence.—Carbon occurs native in the diamond, in graphite (black lead), and in the various forms of coal. In combination it occurs in all organic bodies, petroleum, fats, oils, and in native carbonates, as marble, dolomite, etc.

Varieties.—Carbon exists in three allotropic states : the diamond, the graphite, and amorphous carbon. The **diamond** occurs in alluvial deposits in Brazil, India, Borneo, South Africa, and in small quantities in other localities. The so-called California diamonds and Brazilian pebbles are crystals of quartz, SiO_2. The diamond is pure crystallized carbon, possessing a brilliant luster and a high power of refraction, and is the hardest substance known. It crystallizes in rhombohedra of the first system, but cleaves readily into octahedra. It occurs colorless, as well as colored through all shades of yellow, brown, and black. The sp. gr. is 3.5. Heated in the oxyhydrogen

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* Approximate atomic weights.

blowpipe flame, or in oxygen gas, it burns to carbon dioxide, and is slightly softened by the heat of the electric arc.

Graphite, or **plumbago,** occurs as a native mineral, having a grayish-black color, a luster almost metallic, and a soapy feel. It leaves a black streak upon a white surface, on account of which it is used to make lead-pencils, and is called **black lead.** It sometimes occurs in short, six-sided prisms. It burns in an atmosphere of oxygen with more difficulty than the diamond, furnishing carbon dioxide, and leaving from two to five per cent. of ash. Some of the purer varieties can be made directly into pencils, but this is not common. The poorer varieties are ground to a powder, heated with potassium chlorate, $KClO_3$, and sulphuric acid, H_2SO_4, or with strong nitric acid, washed with water, heated to a red heat, and then mixed with some adhesive material and pressed into cakes. These cakes are then sawed into suitable strips and mounted.

Graphite conducts heat and electricity well. It is also used in the manufacture of crucibles, as a lubricant for very heavy machinery, and as a stove-polish. It may be artificially obtained by fusing amorphous carbon with cast-iron. On cooling the mixture and dissolving the iron with a dilute acid, HCl, graphite is left in the form of minute hexagonal plates. **Amorphous carbon** is found native in the form of many varieties of coal. Artificially, it is prepared by the partial burning or carbonizing of organic matter, such as wood, pitch, blood, etc.

Soot, or **lamp-black,** one of the purest forms of amorphous carbon, is prepared by the imperfect combustion of turpentine, pitch, or heavy oils rich in carbon. It is used principally as a pigment. **Animal charcoal,** or **bone-black,** is obtained by the carbonization of animal matter from slaughter-houses (blood, bones, etc.), and possesses, in a remarkable degree, the power of removing the coloring matter from organic solutions filtered through it. It is used in refining sugar to remove the color from the solution of raw sugar. **Charcoal, carbo ligni** (U. S. P.), is carbonized wood, retaining, usually, the form and grain of the wood and the ash contained in the same. In preparing it, the wood, cut into suitable lengths, is piled up on end, into a conical heap, a trough made of boards being laid from the circumference on one side to the center, to supply air in burning. The whole heap (except a hole at the center on the top) is then covered, first with straw or leaves, and finally with dirt about six or eight inches in thickness. The fire is lighted and is allowed to burn slowly, until the flame almost ceases to come from the hole at the top, or until the gaseous products have all burned off. This opening at the top, as well as the draft-hole, is now covered over

and the fire allowed to smolder for a time, when the heap is torn down and the remaining fire extinguished with water.

Charcoal is used as a fuel, in the manufacture of gunpowder, and sometimes in the construction of filters, as it possesses, although in a feebler degree than animal charcoal, the power of destroying noxious odors and of filtering coloring matters from organic solutions. One volume of it absorbs 90 volumes of NH_3, 55 volumes of H_2S, and 9 volumes of oxygen, at 100° C. (212° F.). It is very porous, and burns with little flame. **Coke** is the porous mass left in the retorts from the destructive distillation of mineral coal in the production of illuminating gas. **Gas-retort carbon** is a compact, hard mass found adhering to the inside of the retorts in the above process of manufacturing coal-gas. It has a metallic luster at times, and is a good conductor of electricity. For this reason, and because of its durability, it is used for the negative plate in the construction of many forms of the galvanic cell, and for the poles in the arc electric light.

Mineral coals, as anthracite, bituminous, brown, and cannel coals, lignite, peat or turf, etc., are the results of a slow decay of vegetable matter, under certain conditions. The proper conditions for the formation of coal seem to be enough water to cover the fallen timber or vegetation, a covering of clay or mud to exclude the air, and the application of pressure to the mass. The liquid and volatile portions are gradually lost, leaving the carbon behind. The final product of this change, assisted by subterranean heat, is **anthracite** coal, which often contains 96 to 98 per cent. of carbon but very little volatile matter. Petroleum oil is believed to be the expelled liquid portions of the wood, separated from the anthracite coal by heat and pressure. **Bituminous** coal is a softer, less compact, less decayed variety. It often exhibits the structure of the wood. It burns with a smoky flame, while the anthracite furnishes very little or no flame. **Brown coal, lignite,** and **wood coal** are names of less perfect varieties than those before mentioned. **Peat,** or **turf,** is a mixture of mud with partially decayed plants and roots, and is obtained from certain marshy districts. It is used as fuel. **Cannel-coal** is a compact, even-textured coal, without luster. It takes fire readily, burning with a clear yellow flame. It has been used for candles ; hence the name.

Properties.—Carbon is insoluble in all ordinary menstrua, but soluble to a slight extent in molten cast-iron, forming a carbide. It is fused and volatilized only in the electric arc. At ordinary temperatures it is permanent in air. At high temperatures it has a strong affinity for oxygen, and on this account it is used as a reducing agent in smelting the ores, from which it removes the oxygen. Indirectly,

it enters into combination with a great many of the elements. Organic bodies are formed of carbon in combination with hydrogen, nitrogen, and oxygen. Most combustible bodies contain carbon.

Official Preparations.—Animal charcoal, carbo animalis (U. S. P., Br.), is prepared from bones by partially burning them and distilling off the volatile products and charring the remaining organic matter. It occurs in granular fragments, or in powder of a dull-black color, which, when ignited, leaves about eighty-five per cent. of ash. This ash should be almost entirely soluble in hot HCl.

When animal charcoal is boiled for a few minutes with a solution of potassium hydroxide, the filtered solution should be colorless, or nearly so.

Carbo Animalis Purificatus (U. S. P., Br.).—This is prepared by heating the above with dilute HCl, to dissolve out the calcium phosphate. The quantity of ash after ignition should not be more than four per cent.

Carbo ligni (U. S. P., Br.) is prepared from soft wood, and very finely powdered. It should be kept in well-closed vessels.

Coal-gas.—Illuminating gas, as it is often called, is made on a large scale by the destructive distillation of bituminous coal. In principle the manufacture is simple, but in practice it requires considerable skill to prepare a good illuminating gas. During the distillation, which is conducted in horizontal, semicylindrical, fire-clay or cast-iron retorts set in brickwork, a variety of products are formed besides the gas; such as tar, heavy oils, lighter oils, steam, ammonia from the nitrogen of the coal, etc. There is left in the retort a porous, friable mass, called **coke.** After the retorts have been used for some weeks, there is to be found lining their inner surfaces a very compact layer of carbon, usually known as **gas-retort carbon.**

The coal is distilled at a bright-red heat and the volatilized products are conducted into a large horizontal iron pipe, half filled with water, into which the pipes from the retorts dip. (See Fig. 58.) This is called the **hydraulic main.** A large part of the **coal-tar** and heavy oils condense in this main. The volatile products are then made to traverse a series of upright tubes in the form of an inverted U, called condensers. The lower end of one limb of each condenser dips under water so as to cool the gas and to wash out the ammonia. After traversing a number of these condensers, where the remainder of the tar, steam, and ammonia are condensed, the gas passes to the purifiers. These are composed of a series of large boxes in which are several perforated shelves or trays holding fresh slaked lime or a mixture of sawdust and iron oxide. The gas is passed slowly through these purifiers,

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so as to expose it to the action of the lime or iron oxide, to remove H_2S, CO_2, and other volatile acids, if present. In some plants there is an additional process of washing the gas by passing it through weak sulphuric acid to remove the small quantity of ammonia still remaining. The tar and ammonia-liquor are sold as by-products. The latter furnishes a very considerable portion of the ammonium compounds of the market. After passing through the purifiers the gas is conducted in underground pipes to the gasometer, to be stored until needed.

The **gasometer** is a very large, tub-shaped vessel made of boiler-iron, floated bottom upward upon water. It is balanced by weights
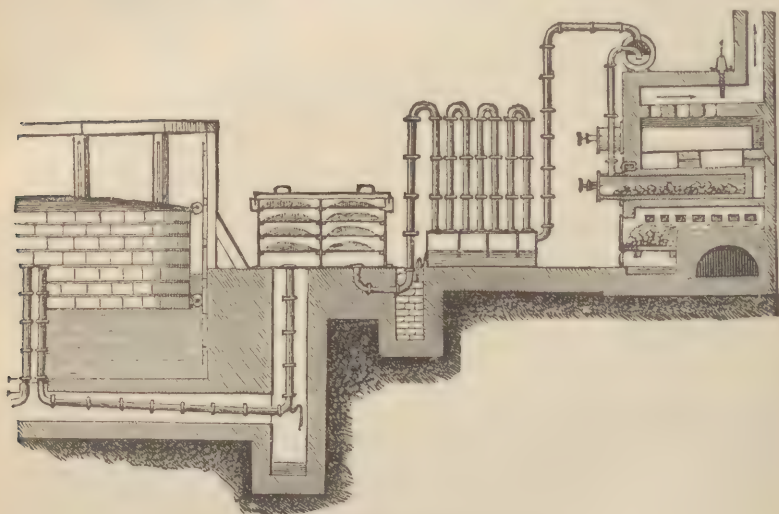
FIG. 58.—THE MANUFACTURE OF COAL-GAS.

attached to chains passing over pulleys, at the top of iron pillars, which are erected around the gasometer for that purpose. As the gas is forced into the gasometer the latter rises out of the water, and sinks again as the gas is used.

Various other processes for the manufacture of gas have been used with varying success; such as the distillation of the heavy petroleum oils, either alone, with coal, or with the admixture of the vapors with air or steam.

Gasolene, or **air-gas**, is air saturated with the vapors of the very volatile oils from petroleum.

Water-gas is very largely used in all large cities, owing to the cheapness of its manufacture. It is made by the action of air and steam—used alternately to maintain the necessary temperature—upon anthracite coal at a red or white heat. The gas thus produced is mixed with vapor from naphtha, and then again strongly heated in tubular retorts, and finally purified as in ordinary coal-gas. This water-gas has very largely replaced the gas made from bituminous coal in the Eastern cities of this country.

Composition.—The composition of coal-gas varies somewhat with the composition of the coal used, and the temperature of the retorts during the distillation.

The following figures represent the composition of coal-gas and water-gas supplied to Brooklyn in 1883:

	COAL-GAS.	WATER-GAS.
Carbon dioxide,	0.0	0.3
Carbon monoxide,	7.9	28.25
Hydrogen,	50.2	30.3
Illuminants (C_2H_4, C_2H_2, etc.),	4.3	12.85
Marsh-gas (CH_4),	29.8	21.45
Nitrogen,	7.8	6.85
	100.00	100.00

Although the destructive distillation of coal is usually conducted primarily for the production of illuminating gas, the side-products are of very great importance.

The aqueous portion of the liquid that condenses in the hydraulic main is known as **ammonia-liquor,** from the fact that it contains various ammonium compounds derived from the nitrogen of the coal. These are chiefly the carbonate, sulphide, cyanide, and sulphocyanate.

This **ammonia-liquor** is perhaps one of the most useful of the side-products of the distillation, because it is the chief source of ammonia, so useful as a fertilizer and for many other purposes.

Coal-tar.—This is the tarry liquid which condenses in the hydraulic main, and from which so many of the compounds of modern organic chemistry are derived. Coal-tar is a very complex mixture, composed chiefly of hydrocarbons. The student should clearly distinguish between **coal-tar** and **petroleum,** which is a natural product obtained from wells. The hydrocarbons are separated from one another by fractional distillation of the tar in iron retorts.

The first distillation is usually into **light oil, heavy oil, dead oil, naphthalene, anthracene,** and **pitch,** or **asphaltum.** These separate portions are then redistilled or otherwise treated. The direct or indirect products of coal-tar are almost without number, and many of them of great importance in the arts.

Carbon forms with chlorine the following compounds : carbon tetra-chloride, CCl_4 ; carbon chloride, C_2Cl_2 ; carbon dichloride, C_2Cl_4 ; carbon trichloride, C_2Cl_6 ; and the oxychloride, $COCl_2$.

It combines directly with some of the metals to form carbides. The carbide of iron is a familiar example. The carbide of calcium has recently been found a valuable commercial product.

Carbon and Oxygen.—There are four oxides of carbon known, having the formulæ C_8O_3, C_4O_3, CO, and CO_2. The first of these compounds is a light-brown powder, formed by heating the suboxide, C_4O_3.

Carbon suboxide is an amorphous extractive matter formed by the action of an electrical current upon carbon monoxide.

Carbon monoxide, CO, is a colorless, tasteless, almost odorless, combustible, and very poisonous gas.

It is always produced when carbon or bodies containing it are burned with an insufficient supply of oxygen or air, or by conducting carbon dioxide over or through red-hot coals. $CO_2 + C = 2CO$. It may be prepared by warming oxalic acid with sulphuric acid.

$$H_2C_2O_4 + H_2SO_4 = H_4SO_5 \text{ (or } H_2O.H_2SO_4) + CO_2 + CO.$$
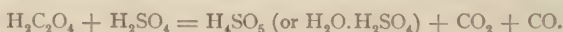
The mixed CO_2 and CO are passed through a solution of sodium hydroxide to absorb the CO_2, and the CO remains. One part of potassium ferrocyanide, warmed with nine parts of H_2SO_4, may be used to give the gas in nearly a pure state. Its density is 14. It is almost insoluble in water, but soluble in a solution of cuprous chloride in ammonium hydroxide. It burns in the air with a bluish-lavender flame, producing the higher oxide, CO_2. Owing to this property, it plays an important part in the reduction of ores in the blast-furnace. It does not support combustion or respiration. It diffuses readily through red-hot cast-iron, and frequently escapes from stoves and hot-air furnaces.

Physiological Effects.—It has the power of combining with the hemoglobin of the blood and of expelling the oxygen. It thus acts as a narcotic poison, causing dizziness, headache, nausea, incoördina-tion of movements, convulsions, and death. If the carbon monoxide be in sufficient quantity to saturate all the hemoglobin, recovery seldom takes place. The blood has a light-red color and does not coagulate after death, or decompose as readily as normal blood. When diluted and examined with the spectroscope, it gives two absorp-tion bands similar to those in number 10, Frontispiece, but they are removed somewhat toward the violet end of the spectrum. If the hemoglobin is only partially saturated recovery may take place, but very slowly—debility, anorexia, etc., remaining for days. Air con-

taining 0.5 per cent. kills birds in three minutes; two per cent. renders a guinea-pig insensible in two minutes. Artificial respiration is of little use. Transfusion of blood or intravenous injection of sterilized salt solution, 0.7 per cent., is the most promising treatment. The sources of danger are open fires, defective draft in chimneys, escape of coal-gas, and especially " water-gas," from defective fittings or from leaks under the ground. When the ground is frozen and the gas escapes into the soil near a dwelling, the gas diffuses through the ground into the cellar, and, as it is thus deprived of its odor, persons may be poisoned and not know where it comes from. Coal-gas poisoning is essentially a poisoning by the carbon monoxide which it contains. Suffocation by coal-gas is not very different from suffocation by other gases, and should be distinguished from poisoning.

Carbon dioxide, carbonic anhydride, CO_2, sometimes called carbonic acid gas, is found free in the air in the proportion of about four parts per 10,000, and in ordinary well-ventilated rooms from five to six parts per 10,000. It is found in volcanic gases and in solution in many mineral springs. It sometimes accumulates in dangerous quantities in mines, wells, and cellars, and is then known as "chokedamp." It may be detected in such places by lowering a candle. It is produced when carbon or its compounds are burned with a free supply of air, by alcoholic and other fermentations, by the respiration of animals, and by slow oxidation of organic matter in the natural process of decay. In the laboratory it is obtained by the action of an acid upon a carbonate.

$$CaCO_3 + 2HCl = CO_2 + CaCl_2 + H_2O.$$

Carbon dioxide, at ordinary temperatures and pressures, is a colorless, transparent, odorless, tasteless (by some thought to be sweetish) gas. Specific gravity = 1.524. Density = 22. Under a pressure of thirty-six atmospheres at 0°C. (32° F.) it is condensed to a colorless, mobile liquid of sp. gr. 0.94. Above 31.9° C. it can not be liquefied at any pressure. This is known as the **critical point in temperature.** When the liquid is exposed to the air it rapidly evaporates, producing a temperature so low as to freeze a portion of it to a snow-like solid, the temperature being sometimes as low as —130° C. (—202° F.). The gas extinguishes the combustion of burning bodies, and animals die very quickly in it. Death has resulted from persons entering mines, wells, and fermenting vats where the gas has accumulated. It is unsafe for a man to venture into a well or other place where a candle will not burn. CO_2 is soluble in its own volume of water at the ordinary temperature and pressure, forming a solution of carbonic acid, H_2CO_3. Common **soda-water** is a solution of the

gas in water under pressure ; it contains no sodium salt, as its name would imply.

Physiological Effects.—These vary with the degree of concentration of the gas and its dilution with other gases. If the gas be pure, it causes death instantly by asphyxia from spasm of the glottis. When somewhat diluted there is, at first, great loss of muscular power : the person becomes livid, sinks down, and dies without a struggle. When still more diluted there is, at first, irritation of the throat ; then giddiness, ringing in the ears, loss of muscular power, with rapid pulse and respiration, and occasionally vomiting and convulsions, which finally end in coma and death.

The amount of the gas that can be tolerated in the air depends not only upon the quantity of it actually present, but also upon the source of it. Thus, when the source of the gas is animal respiration or combustion, the oxygen is withdrawn from the air at the same time, and a much smaller quantity will prove fatal than when the gas is simply added to the normal atmosphere.

If the CO_2 is simply added to the air, 10 per cent. may be regarded as poisonous, and even 8 per cent. will prove injurious. If, on the other hand, the oxygen be increased, an air containing even 20 per cent. may be breathed by animals for a short time without fatal results. A taper will burn in an air containing 8 per cent. of CO_2 provided the oxygen be present in normal quantity, and will burn feebly in such an air containing 10 per cent. Where the CO_2 is produced by respiration the injurious effects are soon perceived, and are due to several causes—viz., the deficiency of oxygen, the presence of too great a quantity of CO_2 and moisture, the rise in temperature, and the action of the organic matter exhaled from the lungs and skin.

The expired air contains from 4 to 5 per cent., or about 0.78 cubic feet of CO_2 per hour, and there is absorbed 0.94 cubic feet of oxygen. A stearin candle gives off 0.5 cubic feet of CO_2 and uses up 1 cubic foot of oxygen. A gas-light burning 5 feet of gas per hour (12 candle-power) gives off very nearly 6 cubic feet of CO_2, or 3.7 times as much as 1 man ; as much heat as 2 men ; removes more oxygen than 5 men. and gives off nearly as much water-vapor as 5 men. More than 6 parts of CO_2 per 10,000 of air renders it oppressive, and should not be allowed. Assuming the amount of CO_2 given off in an hour by an adult to be 0.7 cubic feet, and normal air to contain 4 parts, it would require about 3500 cubic feet of air per hour for each adult occupant of a room, in order that it should not receive more than 2 parts per 10,000 of CO_2. or 2 cubic feet per 10,000. Dr. Parkes fixes the amount necessary at 2000 cubic feet per hour. It is impossible to change the air of a room oftener than 3 or 4 times per hour

without causing uncomfortable drafts; and it would, therefore, require 700 to 1000 cubic feet of room space in order to keep the air of the room in a proper condition. If lights are used, which also pollute the air, a corresponding calculation must be made for them. A common oil lamp (not an argand lamp), or two sperm candles will contaminate the air about as much as an adult man. The English Poor-Law Board's requirements for dormitories, to prevent over-crowding, are:

CUBIC FEET.

1200 for lying-in cases and offensive sick.
 850 " sick.
 700 " infirm. Same room night and day.
 500 " infirm. Separate room during day.
 300 " healthy.

These figures are, of course, too small for general use. Parkes quotes Morin as giving the following amounts of fresh air necessary to be furnished to each adult per hour in the following circumstances :

	DAY.	NIGHT
In barracks, ...	1059 cu. ft. per hour.	2118 cu. ft. per hour.
" workshops, . . .	2118 " "	
" schools, ...	1059 " "	
" hospitals, ...	2825 " "	

In sleeping apartments the amount of space allowed to each individual should be not less than 1000 cubic feet—*i.e.*, a room 10 × 10 × 10 feet. But, as the proportion of carbon dioxide would accumulate slowly, and as a much larger amount of the gas may be borne without serious discomfort, even one-half this capacity may be tolerated with little inconvenience beyond a feeling of fatigue or sleepiness in the morning. Dr. Tidy regards 400 cubic feet as the very smallest amount of space that should be allowed to each person in a sleeping room to avoid serious overcrowding. Analysis shows that the foulest air in an occupied room is at the ceiling. The heat of the body or of a lamp causes an expansion of the air about them, and an upward current of heated CO_2, water-vapor, etc. These gases reach the ceiling before they cool sufficiently to stop this upward current, and before there is time for perfect diffusion. The upper galleries in theaters are supplied with impure air from the main floor and lower galleries, and from the gas-lights. Fresh air should always be admitted to a room near the floor, and the outlet for impure air should be at or near the ceiling. It must be remembered that the law of diffusion of gases does not allow the CO_2 to accumulate in one part of the room

and remain there for any considerable time. but mixes it evenly through the air.

Nor is this diffusion confined within a room. It takes place through porous walls between the indoor and outdoor air, especially in winter, **when there is much difference in the temperature of the two.** Indeed, a very fair amount of ventilation may be effected in this way. where the walls are of brick or stone, and not papered or painted inside.

Carbon dioxide exists in the blood partly in solution in the serum, partly combined as sodium bicarbonate, partly as sodium phospho-carbonate, and partly combined with the hemoglobin of the corpuscles. Putrefaction of the body after CO_2 poisoning is slow, while animal heat and rigidity are very persistent.

Tests for Carbon Dioxide.—If the quantity exceeds twelve per cent., a taper is extinguished. Lime-water and baryta-water absorb CO_2 from the air, and are rendered cloudy by it, from the precipitation of the carbonate of calcium or barium.

Advantage is taken of this fact to estimate the quantity of CO_2 in air. A simple way of testing whether the air of a room contains too much CO_2 is to select a quart bottle, fill it with the air of the room by first filling the bottle with water and then pouring it out slowly, and add to the bottle one cubic centimeter ($\mathfrak{m}$ xvss) of clear and well-saturated lime-water, faintly colored with phenolphthalein. Add a little pure water, cork, shake, and let stand for a few hours. Pure outdoor air contains just sufficient CO_2 to decolorize the lime-water. Indoor air should not decolorize more than 1.3 c.c. of lime-water.

Carbonic Acid and Carbonates.—CO_2 is soluble in water, with which it combines to form carbonic acid, H_2CO_3.

$$H_2O + CO_2 = H_2CO_3.$$
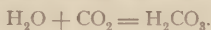
Carbonic acid is a feeble, dibasic acid, forming a double series of salts, the **carbonates** and **acid-** or **bi-carbonates.** As mentioned above, ''soda-water'' is a solution of carbonic acid in water, kept under pressure. When the pressure is removed, a large portion of the acid undergoes decomposition into the anhydride, CO_2, and water. The same decomposition, with effervescence, takes place when we prepare the acid by treating a carbonate with a stronger acid. The carbonates of gold, arsenic, antimony, and aluminum are unknown. The carbonates of K, Na, Li, Cs, and Rb are soluble in water and are not decomposed by heat ; while the carbonates of all the other metals are insoluble and are decomposed by heat, giving the oxides of the metals.

$$CaCO_3 = CaO + CO_2.$$
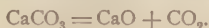
The bicarbonates are formed by passing carbon dioxide through solutions of the alkaline carbonates.

$$Na_2CO_3 + H_2O + CO_2 = 2HNaCO_3.$$
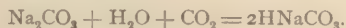
They are converted into the carbonates again by heat. The carbonates of ammonium are volatilized by heat. Water charged with carbonic acid dissolves the carbonates of some of the metals, as calcium, magnesium, iron, copper, lead, etc., giving rise, in the case of the first two, to a hard water. This hardness is deposited again on boiling the solution, or even on free exposure to the air. CO_2 thus plays an important part in certain geological formations.

Carbon and sulphur, carbon disulphide, carbonei disulphidum (U. S. P.), CS_2, is formed, like the dioxide, by the direct union of the elements. When the vapor of sulphur is passed over charcoal heated to redness, the elements combine, producing the vapor of carbon disulphide, which condenses into a very volatile, colorless, mobile liquid, possessing a peculiar, disagreeable odor. It refracts light strongly, and for this reason is used to fill hollow glass prisms for the spectroscope. It is combustible, burning with a blue flame, and has been suggested as a means of furnishing sulphurous oxide for fumigation, by burning a mixture of CS_2 and alcohol in a lamp. Specific gravity, 1.268 to 1.269 at 15° C. (59° F.).

The vapor mixed with air forms an explosive mixture, and mixed with nitrous oxide it burns with a very brilliant flame. It is insoluble in water, but is miscible with alcohol and ether. It is a ready solvent for sulphur, phosphorus, caoutchouc (india-rubber), fats, oils, and iodine, with the last of which it forms a violet-red solution. CS_2 dissolves in a solution of the alkaline sulphides, forming **sulphocarbonates** or **thiocarbonates.** $CS_2 + K_2S = K_2CS_3$. CS_2 may be regarded as the anhydride of thiocarbonic acid, H_2CS_3, obtained by adding hydrochloric acid to a thiocarbonate.

Pharmacopœial Requirements.—Carbon disulphide should not affect the color of blue litmus paper moistened with water (absence of sulphur dioxide). It should leave no residue when evaporated spontaneously (absence of sulphur). Test-solution of lead acetate should not be blackened when agitated with it (absence of hydrogen sulphide). **Carbon monosulphide,** CS, a brown-red powder, and a sulphide having the formula C_3S_2, and an oxysulphide, COS, are also known.

Carbon and Nitrogen.—Preparation.—Although carbon and nitrogen can not be made to unite directly, yet carbon compounds containing nitrogen, when heated with potassium hydroxide, yield potassium cyanide, KCN ; and, in the presence of iron, form potas-

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sium ferrocyanide, or **yellow prussiate of potash.** From these
two compounds all the long list of compounds containing the radical
CN are prepared. Cyanogen and the cyanides are frequently regarded
as organic compounds. They are treated here among the inorganic
substances, because the compounds used in medicine and pharmacy are
mostly metallic salts.

Cyanogen, $(CN)_2$, is most easily prepared by heating mercuric or
argentic cyanide, or by heating a mixture of two parts of well-dried
potassium ferrocyanide and three parts of mercuric chloride.

Properties.—Cyanogen is a colorless gas possessing a pungent
odor. It is soluble in one-fourth its volume of water and one-
twentieth its volume of alcohol. It is easily condensed to a liquid at
—20.7° C. (—5° F.), or at ordinary temperatures by a pressure of four
atmospheres. At —34° C. (—29.2° F.) it freezes to a snow-like
solid. It burns in the air with a purple-red flame. The free cyanogen
molecule is composed of two cyanogen radicals, CN—CN. The radical
CN (symbol, Cy) is a monad, negative, or acid radical, resembling
the elements of the chlorine group in its chemical behavior, and
forming a series of cyanides resembling the chlorides, thus :

Potassium chloride,	KCl.	Potassium cyanide,	KCy.
Silver chloride,	AgCl.	Silver cyanide,	AgCy.
Mercuric chloride,	$HgCl_2$.	Mercuric cyanide,	$HgCy_2$.

Hydrocyanic acid, prussic acid, HCy, is most readily ob-
tained by decomposing the metallic cyanides with sulphuric or hydro-
chloric acid.

$$KCy + H_2SO_4 = HCy + KHSO_4.$$
$$AgCy + HCl = AgCl + HCy.$$
$$2K_4FeCy_6 + 6H_2SO_4 = FeK_2FeCy_6 + 6KHSO_4 + 6HCy.$$
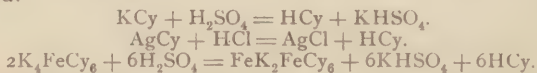
The acid boils at 26.5° C. (79.7° F.), and is soluble in water, from
which it gradually escapes. It is a colorless liquid, of a characteristic
odor and taste, resembling those of bitter almonds, the oil of which
contains from five to fourteen per cent. of this acid. It is also a con-
stituent of laurel-water.

Acidum hydrocyanicum dilutum (U. S. P., Br.) contains
two per cent. of HCy, while the French Pharmacopœia requires the
acid to contain ten per cent.

Preparation.—The U. S. P. directs that potassium ferrocyanide
be treated in a retort with sulphuric acid and the resulting HCy
distilled into a receiver containing water. The product is then
assayed, and diluted with distilled water to bring it to the strength of
two per cent. A formula is also given for preparing the acid extem-
poraneously. Silver cyanide and hydrochloric acid are shaken in a

glass-stoppered bottle, and when the precipitate has subsided the clear liquid is poured off, ready for use.

Cyanides.—Prussic acid forms a series of compounds known as cyanides, which resemble the halogen compounds. Like the acid, they are all more or less poisonous. The cyanides of potassium, mercury, and silver are best known. The first is soluble in water; the other two are insoluble. The potassium salt is used largely in photography, in electrometallurgy, and in the extraction of gold from its ores.

Toxicology.—Hydrocyanic acid and the cyanides are very poisonous. One drop of the pure acid is enough to cause instant death. Accidents are liable to occur from the use of the cyanides, or from the acid, or vegetable substances containing **amygdalin,** a body which easily undergoes decomposition into prussic acid and other products. Bitter almonds, cherry-laurel, the pits of the common cherry, plum, peach, and sloe, may be mentioned as the most common of these. In England, poisoning by cyanides ranks second in order of frequency of all cases of poisoning. One grain of HCy and 2.4 grains of potassium cyanide are sufficient to cause death in man. The symptoms of poisoning by HCy and KCy are very nearly the same—first a salivation, then constriction of the throat, giddiness, and insensibility. The person then falls, usually in a convulsion ; respiration and pulse become irregular, and finally cease. The symptoms commence from ten seconds to one minute after swallowing the poison, depending somewhat upon the dose and form of administration. In some cases death is almost instantaneous ; in others it is prolonged to fifteen minutes, or longer. Hydrocyanic acid enters the blood, forming a compound with the hemoglobin, passes to the medulla, and paralyzes the respiratory centers. The **postmortem appearances** are mainly those of suffocation, and everywhere there is the odor of the acid, unless concealed by putrefactive odors. When potassium cyanide has been used, there is usually inflammation of the stomach, due to its caustic action.

Chronic poisoning by cyanides may occur in photographers, gilders, and electroplaters. The symptoms are : headache, giddiness, noises in the ears, pains in the region of the heart, difficult respiration, loss of appetite, nausea, obstinate constipation, full pulse, pallor, and offensive breath.

Treatment.—When there is time, use cold douches, ammonia inhalations, chloride of lime alone or moistened with vinegar and held to the nose, friction, electricity, and artificial respiration. The best antidote is a mixture of ferrous and ferric sulphates, with sodium or potassium hydroxide or carbonate. Usually, however, there is not sufficient time to apply these remedies, except in cases of poisoning

by the vegetable substances above mentioned as containing HCy, and in chronic poisoning.

Tests.—(1) Silver nitrate precipitates the acid as silver cyanide —a white, curdy precipitate, insoluble in cold or weak nitric acid. A glass rod moistened with $AgNO_2$ and held in the vapor is rendered milky. (2) Add **liquor potassæ,** or a solution of potassium hydroxide, then a solution of ferrous sulphate mixed with ferric sulphate, then a small quantity of sulphuric acid, when the blue color of Prussian blue will appear. (3) To a small portion of the suspected liquid, in a wide test-tube or crucible, add diluted sulphuric or hydrochloric acid. Invert over this a watch-glass, convex side down, with one or two drops of yellow ammonium sulphide upon the under side of it. Warm the crucible gently, and after a few minutes remove the watch-glass, warm, and evaporate the ammonium sulphide by blowing upon it. Now touch the stain with a drop of ferric chloride, when a blood-red stain will make its appearance, due to the formation of sulphocyanate of ammonium on the glass, with which the iron gives a red color. This test is easy to perform, is applicable to organic mixtures, and is quite delicate.

Assay.—Mix, in a flask of about 100 c.c. capacity, 0.270 gm. of the HCy to be tested with a little water and enough magnesia, MgO, to make the mixture opaque. Add to this two or three drops of test-solution of potassium chromate, and then $\frac{N}{10}$ silver nitrate solution from a burette, until a permanent red tint is produced. Each cubic centimeter of the silver nitrate solution used represents 1 per cent. (or 0.0027 gm.) of pure HCy.

Cyanic Acid.—HOCy. Metallic cyanides readily take up oxygen when fused with potassium nitrate, or even the oxides of some of the metals, and form cyanates. Cyanic acid may be prepared by decomposing its salts with diluted acids. It is unstable, and breaks up into carbon dioxide and ammonia.

$$HOCN + H_2O = NH_3 + CO_2.$$
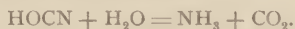
Of the cyanates, the ammonium cyanate is the most interesting, as its solution in water, on being heated, forms urea, a body isomeric with it, and a well-known excretory substance found in urine.

$$NH_4CNO = CO(NH_2)_2.$$
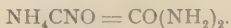
This is interesting as being the first animal substance prepared by synthesis.

Sulphocyanates.—**Potassium sulphocyanate** is prepared by fusing potassium ferrocyanide and sulphur together and exhausting the

fused mass with alcohol. On evaporating the alcohol a white, crystalline salt is obtained, soluble in water, and having the formula KSCy.

Ammonium sulphocyanate, NH_4SCy, is prepared by heating hydrocyanic acid with yellow ammonium sulphide.

The principal interest attached to these salts is their use as tests for ferric iron salts, with which they give a blood-red solution. The sodium salt is found in traces in human saliva.

Mercuric sulphocyanate, formed by precipitating mercuric nitrate with potassium sulphocyanate, is decomposed by heat, the mass swelling up and leaving a voluminous residue. It is used in making the toy, **Pharaoh's serpents.**

Compound Cyanides.—Cyanogen shows a remarkable tendency to form complex compounds. Among these more complex compounds are two series of bodies in which cyanogen and iron form the radical. Of these, the **ferrocyanides** and **ferricyanides** of potassium and iron will be mentioned here.

Potassium ferrocyanide, $K_4Fe(CN)_6$, **yellow prussiate of potash,** is an important commercial product, manufactured on a large scale by fusing nitrogenous animal matter (horns, hoofs, leather scraps, etc.), in a closed crucible with potassium carbonate and iron filings, treating the fused mass with water, and crystallizing. The salt is thus obtained in large, yellow, tabular crystals. It is used in dyeing, in preparing certain pigments, and as a source of all the other cyanogen compounds. By simple fusion potassium cyanide, KCy, is prepared.

$$K_4FeCy_6 = 4KCy + FeC_2 + N_2.$$
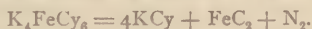
From a solution of the salt various other ferrocyanides are prepared by precipitation. Of these, **Prussian blue** (ferric ferrocyanide), prepared by adding to a solution of potassium ferrocyanide a solution of some ferric salt, is used as a pigment and as a medicine. With a ferrous salt the precipitate is white, but quickly becomes blue by oxidation. This test serves to distinguish ferrous from ferric salts. With cupric salts we obtain a reddish-brown precipitate, Cu_2FeCy_6.

Ferricyanides.—By passing chlorine through a solution of K_4FeCy_6 a compound is formed in which the iron of the radical is tetrad and the radical itself becomes hexad. $K_6(Fe_2Cy_{12})^{vi}$. On evaporating we obtain dark-red crystals of **potassium ferricyanide,** or **red prussiate of potash.** With ferrous salts a solution of this salt gives a deep-blue precipitate of ferrous ferricyanide, $Fe_3Fe_2Cy_{12}$, Turnbull's blue. Ferric salts give no precipitate or coloration, and thus we distinguish ferric from ferrous salts.

Ferric ferrous cyanide = Prussian blue.
Ferrous ferric cyanide = Turnbull's blue.

The further consideration of the carbon compounds will be found in Part IV.

SILICIUM—SILICON.

$Si = 28$.

Occurrence.—It occurs in native rocks, either as silicic oxide, SiO_2, **quartz, amethyst, carnelian,** etc., or combined with various metallic oxides as silicates. **Clay** is principally a silicate of aluminum colored with iron and vegetable matter. This, next to oxygen, is the most abundant of the elements. Neither the element nor its compounds are of much interest to pharmaceutical or medical students.

The element never occurs native, but may be prepared in three allotropic states: **amorphous silicon, graphitic silicon,** and **crystallized silicon,** somewhat resembling the three states of carbon.

Compounds.—**Silicic hydride,** SiH_4, is obtained as a colorless, spontaneously inflammable gas, by the electrolysis of a solution of common salt, using for the positive electrode aluminum containing silicon.

Silicic chloride, $SiCl_4$, is a colorless, volatile liquid possessing an irritating odor. The bromide, $SiBr_4$, and fluoride, SiF_4, are also known. This latter is decomposed by water, forming **hydro-fluo-silicic acid,** H_2F_6Si.

Silicic oxide, or **anhydride,** SiO_2, is the only known oxide of this element, and exists in a pure state in quartz crystal. It may be prepared artificially by adding hydrochloric acid to a concentrated solution of soluble or water glass, filtering, washing, and heating the residue to expel the water. Artificially prepared, it is a fine, white, tasteless powder, fusible with great difficulty, and not sensibly soluble in water or acids, with the exception of hydrofluoric acid. Its sp. gr. is 2.66. When fused with potassium or sodium carbonates or hydroxides, it forms a silicate of these metals, or glass. When these alkalies are in excess, the glass is soluble in water, the degree of solubility increasing with the proportion of alkaline salt used. This compound is known as **soluble glass** or **water glass.**

Silicic Acid and Silicates.—The normal silicic acid has the formula H_4SiO_4, and is only known in solution in water. It may be prepared by adding hydrochloric acid to a very dilute solution of an alkaline silicate, but it is unstable. The acid is very prone to liberate a portion of its water and form acids of the condensed types—*i. e.*, two or more molecules unite and liberate one or more molecules of water. The native silicates are very complex in structure, and are usually formed on this condensed plan.

Glass.—Common glass is a mixture of several silicates, in which there is an excess of silica, the principal ones used being sodium, calcium, and lead silicates. By the addition of small quantities of metallic oxides, various colors are imparted to the glass; thus, cobalt gives a blue, manganese an amethyst, cuprous oxide a ruby, cupric oxide a bluish-green, chromium a greenish-yellow, ferric oxide a brownish-yellow or black, and ferrous oxide the ordinary green bottle-glass.

The element **germanium** is not of sufficient interest to merit an extended description here.

TIN (Stannum).

Sn = 118. Specific gravity, 7.3.

Occurrence.—Tin was known before the Christian era. It is said to have been found native. The chief ore is **cassiterite**, or **tin stone**, SnO_2. The metal is not abundant and the mines are but few. Those of Cornwall and Banca are best known. Commercial tin is seldom pure, but is liable to contain lead, copper, iron, zinc, antimony, or arsenic.

Properties and Uses.—Tin is a bluish-white, soft metal, malleable, ductile, and fusing at 220° C. (428° F.). At 100° C. (212° F.) it may be drawn into wire, but at 200° C. it is so brittle that it may be pulverized. It oxidizes readily when in the melted state, and at higher temperatures it takes fire and burns to SnO_2. At ordinary temperatures it is fairly permanent in the air. It dissolves in hot hydrochloric acid and in diluted nitric acid, and in hot concentrated solutions of sodium and potassium hydroxides. As tin does not tarnish in the air, or is not easily attacked by the organic acids, it is much used to prepare culinary vessels. Owing to its cost and brittleness it is usually employed to coat over sheet-iron and copper. Ordinary **sheet-tin** is sheet-iron covered with tin by immersing the previously cleansed iron in a bath of melted tin. To prevent the oxidation and waste of the tin while in the melted state, it is covered with a layer of melted tallow. The article to be tinned is dipped through the tallow into the melted tin, thence into another bath of tallow to allow the excess of tin to run off.

An alloy of tin and lead is largely used for tinning iron and copper, to reduce the cost. This alloy is corroded by ordinary water, and should never be used for culinary vessels or for canning vegetables or fruits, on account of the lead. Brass and copper articles may be given a thin layer by immersing them in a boiling solution of tin chloride in contact with pieces of metallic tin. Mirrors are coated

with an amalgam of tin in such a way as to exclude all air. The ordinary tin-foil, used as wrapping material, is made by rolling a sheet of lead between two sheets of tin.

Compounds.—Tin forms two classes of compounds, corresponding to the dyad and tetrad conditions respectively. Of these, the most important are the following :

	STANNOUS COMPOUNDS.	STANNIC COMPOUNDS.
Chlorides, ...	$SnCl_2$.	$SnCl_4$.
Oxides, ...	SnO.	SnO_2.
Hydroxide, ...	$Sn_2O(OH)_2$.	. . .
Stannic acid, ...		H_2SnO_3.
Metastannic acid, ...		$H_{10}Sn_5O_{15}$.
Nitrates, ...	$Sn(NO_3)_2$.	$Sn(NO_3)_4$.
Sulphates, ...	$SnSO_4$.	$Sn(SO_4)_2$.
Sulphides, ...	SnS.	SnS_2.

Of these compounds the most important is **stannous chloride,** $SnCl_2$. It is prepared by treating tin with dry HCl, or mercuric chloride. When tin is dissolved in HCl and the solution is evaporated and cooled, it deposits crystals of $SnCl_2 . 2H_2O$. These crystals dissolve in about one-third their volume of water, but are decomposed by a large quantity, forming the oxychloride. When the solution of this salt is exposed to air, it absorbs oxygen and deposits the oxychloride. Stannous chloride is a strong reducing agent, and is used as such in the laboratory. It is used as a mordant in dyeing. **Stannous sulphide** is produced as a brown powder when H_2S is conducted through a solution containing a stannous salt. It is insoluble in diluted acids, but soluble in alkaline sulphides, and in hot, strong HCl. **Stannic sulphide,** SnS_2. is commonly known as **mosaic gold** or **bronze powder,** used for decorative work. It is made by heating in a flask or retort a mixture of 12 parts of tin and 6 parts of mercury, and mixing this amalgam with 6 parts of sulphur and 7 parts of ammonium chloride. On applying heat to this mixture, the mercury and ammonium chloride are volatilized and the mosaic gold is left, as a beautiful golden-colored powder.

Stannic oxide, SnO_2, occurs native in the mineral cassiterite. When prepared artificially, by roasting tin or its hydroxide, it appears as a white powder. It is used in the manufacture of opaque white glass. Stannic oxide is used as a polishing powder under the name of "**putty powder.**"

The tin salts have found little use in medicine.

Toxicology.—The salts of tin have feeble toxic properties. The chlorides are poisonous, belonging to the irritant poisons. As the chlorides are used in dye-works, they have been taken by mistake,

and have caused death or serious symptoms. The symptoms do not appear to be constant or uniform, but there is usually vomiting, pain, depression of the heart's action, diarrhea, and delirium.

The treatment is to encourage vomiting and give milk freely. Ammonium carbonate may be given, which precipitates the tin in a comparatively insoluble and inert condition. The chlorides are decomposed by nearly all the animal fluids, and also by vegetable infusions.

The effects of small doses of tin continued for a long time have not been clearly defined.

LEAD (Plumbum).

$$Pb = 207.$$

Occurrence.—The most abundant ore found native is **galena**, or **galenite**, PbS. Other ores are **cerussite**, $PbCO_3$; **crocoisite**, $PbCrO_4$; **wulfenite**, $PbMoO_4$; and **pyromorphite**, $Pb_3(PO_4)_2$.

Preparation.—For this purpose **galenite** is almost exclusively employed. The ore is first roasted in the air, by which a portion of the lead sulphide is converted into oxide and another part into sulphate.

$$2PbS + 3O_2 = 2PbO + 2SO_2$$
$$\text{and } 2PbS + 4O_2 = 2PbSO_4.$$
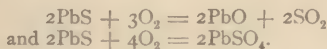
These two products are then strongly heated in a reverberatory furnace, when they react as follows :

$$2PbO + PbS = 3Pb + SO_2$$
$$\text{and } PbSO_4 + PbS = 2Pb + 2SO_2.$$
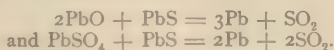
If the galena contains much silver, this is separated by crystallization and cupellation.

Properties.—Lead is a bluish-white metal, brilliant upon freshly cut surfaces, but soon tarnishes. It is soft, malleable, and pliable, but not very ductile. Specific gravity, 11.37. It fuses at 334° C. (633° F.). It is a poor conductor of electricity, but a better conductor of heat.

When exposed to the air it oxidizes slightly. It is not acted upon by pure water deprived of air, but by the contact of air and water it oxidizes to the hydroxide, $Pb(OH)_2$, which is slightly soluble in water. If the water contains carbon dioxide, carbonates, or sulphates, very little lead goes into solution, but it is coated with an insoluble layer of lead carbonate or sulphate. If the carbon dioxide

be under pressure, as in soda-water, the carbonate formed is somewhat soluble in the water.

The solvent action of water upon lead is increased, however, by the presence of nitrates and nitrites. These facts are of great practical importance, as lead pipes are very frequently employed for conducting potable waters.

Sulphuric and hydrochloric acids have but little effect on lead, especially if cold, owing to the insolubility of its sulphate and chloride. Nitric acid dissolves it readily. Zinc, tin, and iron precipitate this metal from its solutions.

There are several useful alloys of lead. Alloyed with an equal part of tin, it fuses at 186° C. (366.8° F.), and is used for **soft solder.** Type-metal is an alloy of four or five parts of lead and one of antimony ; the proportions vary considerably.

Lead chloride, $PbCl_2$, separates as a white precipitate when hydrochloric acid is added to a concentrated solution of a lead salt. It is nearly insoluble in cold water, but dissolves in thirty parts of hot water, from which solution it crystallizes, on cooling, in white, shining needles. At a red heat it fuses to a horn-like mass.

Lead iodide, plumbi iodidum (U. S. P., Br.), PbI_2, is precipitated from lead solutions by potassium iodide as a bright yellow, crystalline powder. It is practically insoluble in cold water, but more soluble in boiling water, from which it crystallizes, on cooling, in beautiful, gold-colored, glistening crystals. An ointment of this salt is official. Exposed to light and moisture, it decomposes, with the liberation of iodine.

Lead oxide, protoxide, massicot, litharge, plumbi oxidum (U. S. P., Br.), PbO, is prepared by heating lead, its carbonate or nitrate, in the air. Much of it is obtained as a by-product, in the extraction of silver from galena. When fused, it is known as **litharge ;** the powder as **massicot.** The former is a reddish-yellow or brown mass of rhombic scales ; the latter is a yellow, amorphous powder, differing from litharge in color and texture, but not in composition.

Lead oxide has strong basic properties. It absorbs carbon dioxide from the air and imparts an alkaline reaction to water, in which it dissolves as hydroxide. Like other strong bases, it saponifies fats when heated with them, to form lead soaps, or **lead plaster.** It dissolves readily in nitric or hot acetic acid, with the formation of nitrate or acetate of lead. It fuses at a red heat. If fused in an earthen crucible, it attacks the crucible and forms a silicate, and thus perforates the crucible. When heated to 300° C. (572° F.) in contact with air, it is slowly oxidized to a bright-red powder, **minium,** or **red lead.**

Plumboso-plumbic oxide, minium, red lead, Pb_3O_4, or $2PbO.PbO_2$, is prepared, as already stated, by roasting litharge at a temperature of $300°$ C. ($572°$ F.), and is used as a pigment and in the manufacture of glass. Its composition is probably expressed by the formula Pb_3O_4; or, as one molecule of the dioxide combined with two of the monoxide; or, as the lead salt of plumbic acid.

It is a brilliant red powder, of a specific gravity of 8.62. When strongly heated, or subjected to the action of reducing agents, it is converted into litharge. Nitric acid dissolves the monoxide, leaving the dioxide, the color changing to brown.

As occurring in commerce, it is frequently contaminated with oxides of iron or brickdust. It should dissolve in dilute nitric acid to which a little sugar has been added.

Lead dioxide, peroxide of lead, puce oxide of lead, binoxide of lead, plumbic anhydride may be prepared by dissolving the monoxide out of minium with dilute nitric acid, or by the action of chlorine upon lead carbonate suspended in water.

It is a dark, reddish-brown powder, insoluble in water; sp. gr., 8.903 to 9.190. Heat drives off half its oxygen, converting it into monoxide. It is therefore, when heated, a valuable oxidizing agent.

Plumbic acid is formed as crystalline plates at the positive electrode, when alkaline solutions of the lead salts are subjected to electrolysis.

Lead dioxide dissolves in strong solutions of the alkaline hydroxides to form well-defined but unstable **plumbates.** Potassium plumbate may be obtained in cubic crystals by dissolving the hydroxide in potassium hydroxide and cooling the solution. It is decomposed by water.

Lead nitrate, plumbi nitras (U. S. P., Br.), $Pb(NO_3)_2$, is obtained by dissolving lead or its oxides in an excess of nitric acid.

$$PbO + 2HNO_3 = Pb(NO_3)_2 + H_2O.$$
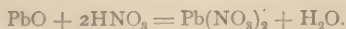
It forms anhydrous, octahedral crystals, soluble in two parts of water at $15°$ C. ($59°$ F.) and 0.7 part at $100°$ C. ($212°$ F.). At a red heat it melts, and is decomposed into PbO, NO_2, and oxygen.

Lead sulphate, $PbSO_4$, occurs in the mineral **anglesite** in rhombic crystals, isomorphous with barium sulphate. It is produced by the double decomposition between a sulphate and a soluble lead salt.

$$Pb(NO_3)_2 + Na_2SO_4 = PbSO_4 + 2NaNO_3.$$
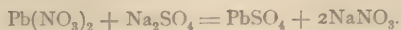
It is insoluble in water, but readily soluble in concentrated sulphuric acid. The commercial acid always contains it.

Lead carbonate, $PbCO_3$, occurs as **cerussite.** **Plumbi carbonas** (U. S. P.) has the composition $(PbCO_3)_2 . Pb(OH)_2$. It may be produced by double decomposition between a lead salt and a soluble carbonate, or by passing carbon dioxide through a neutral solution of a lead salt. **White lead** is usually prepared, commercially, by treating thin sheets of lead with acetic acid and then exposing the acetate to carbon dioxide. The lead, rolled into sheets, is placed in earthen jars containing a small quantity of vinegar at the bottom, but not in contact with the lead. Great numbers of the jars, after being thus charged, are buried in stable-manure or spent tan-bark. By the decomposition of the bark or manure considerable carbon dioxide and heat are produced. The heat volatilizes a portion of the vinegar, which, acting upon the lead, produces the basic acetate $Pb(C_2 H_3O_2)_2 . Pb(OH)_2$. The carbon dioxide acts upon the acetate, and converts it into a basic or hydrocarbonate of lead having the formula :

$$(PbCO_3)_2Pb(OH)_2.$$
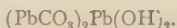
The acetic acid thus set free acts upon a fresh portion of the lead. After the lapse of about six weeks the pile is taken down, the sheets are taken out, and the carbonate detached from them by passing them through rollers or by pounding. The white powder is then ground with oil and sent into the market as '' **white lead.**''

White lead is largely used in oil-painting, forming a part of all but the darkest colors. As it is poisonous, and is darkened by the action of hydrogen sulphide in the atmosphere, it is at present being more and more replaced by **zinc white,** ZnO, and **permanent white,** $BaSO_4$.

Lead sulphide, PbS, occurs in the mineral **galena.** It is precipitated, as a black powder, from solutions of lead salts by hydrogen sulphide or by alkaline sulphydrates. The native sulphide is bluish-gray and has a metallic luster. Specific gravity, 7.58. The sulphide obtained by precipitation has a sp. gr. of 6.924. It is insoluble in dilute acids.

Lead acetate, salt of saturn, sugar of lead, plumbi acetas (U. S. P., Br.), $Pb(C_2H_3O_2)_2 . 3H_2O$, is prepared by dissolving litharge in acetic acid ; or by exposing lead to the action of acetic acid and air, evaporating, and crystallizing. It forms large, oblique, rhombic prisms, having a sweetish, metallic taste. It dissolves in 2.3 parts of water at 15° C. (59° F.), and in 21 parts of alcohol, forming solutions which have an acid reaction upon test-paper. On exposure to the air the crystals effloresce upon the surface and are partly converted into carbonate. Several **subacetates,** or **basic acetates,** are known. The only one of these requiring mention is that having the formula

$Pb_2O(C_2H_3O_2)_2$. This is the chief constituent of **liquor plumbi subacetatis** (U. S. P., Br.), or **Goulard's extract**, which is obtained by boiling a solution of the neutral acetate with lead monoxide in fine powder. When exposed to the air, this solution absorbs CO_2 and becomes milky from the formation of lead carbonate.

Lead chromate, $PbCrO_4$, is formed by precipitating lead nitrate or acetate with potassium chromate.

$$Pb(NO_3)_2 + K_2CrO_4 = PbCrO_4 + 2KNO_3.$$
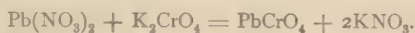
It is used as a pigment, under the name of **chrome yellow.** Recently its fraudulent use as an artificial coloring agent in manufactured food-products has been discovered. It is insoluble in water, but soluble in strong alkalies.

Physiological Action of Lead.—All of the compounds of lead that are soluble, and those that are themselves insoluble, but that are readily convertible into soluble compounds by the action of air, water, or the digestive fluids, are poisonous.

The chronic form of lead-poisoning, **painters' colic**, is very common, and is produced by the continuous absorption of small quantities of the metal or its compounds, either by the skin, the lungs, or the stomach. Although metallic lead is inert, its absorption will cause symptoms of poisoning from its being converted within the body into poisonous compounds. Some of the methods by which it may be introduced are: the drinking of water that has been in contact with the metal; the use of food, tobacco, etc., that has been wrapped in tin-foil containing lead; the drinking of beer or other beverages that have been kept in pewter vessels; and the handling of the metal, its salts, or its alloys by artisans. Almost all of the commoner compounds of lead may give rise to chronic poisoning. Probably the carbonate is the cause of more cases in painters, artists, manufacturers of paint, and persons sleeping in freshly painted apartments than any other lead compound.

Acute lead-poisoning is comparatively rare, and is not often fatal. It is generally caused by the ingestion of a single large dose of the acetate, subacetate, carbonate, or red lead.

When it occurs magnesium sulphate should be given, as it forms with it an insoluble lead sulphate.

If the metal be once absorbed, it is eliminated slowly, as it tends to become fixed by combination with the proteids of the body. This compound is rendered soluble by potassium iodide. It is eliminated by the urine, perspiration, and bile.

On account of the many ways in which it may be introduced,

great caution is necessary in drawing conclusions from traces of lead found in the body after death.

The remaining metals of Group IV are titanium, zirconium, cerium, and thorium. Of these, the only one that has found use in medicine is cerium.

Cerium is a somewhat rare metal found in a number of minerals as a silicate, more especially in **cerite.** The element may be obtained by the electrolysis of cerous chloride. It resembles iron in most of its physical properties. Like iron, it forms two series of compounds.

Cerium oxalate, cerii oxalas (U. S. P., Br.), $Ce_2(C_2O_4)_3 \cdot 9H_2O$, is used in medicine and is prepared by precipitating cerous chloride with ammonium oxalate. It is a white powder, permanent in the air, odorless, tasteless, insoluble in water or alcohol, but soluble in hydrochloric acid. On heating the salt it decomposes, leaving a reddish-yellow residue of Ce_2O_3.

GROUP I.—THE ALKALI METALS.

1. **Lithium,** 7	4. **Rubidium,** 85
2. **Sodium,** 23	5. **Cesium,** 133
3. **Potassium,** 39	6. **(Ammonium),** $NH_4 =$ 18

The metals of this group present a great similarity in their chemical and physical properties. When exposed to the air, they all readily oxidize. They decompose water violently, with the formation of strong basic hydroxides which dissolve in the excess of water. The hydroxides thus formed are called **caustic alkalies** (caustic potash, caustic soda); hence the name alkali metal. Nearly all of the salts of these metals are soluble, and most of them, when in solution, turn red litmus blue—*i. e.,* they give an **alkaline reaction.** They form but one chloride, one iodide, and one bromide.

LITHIUM.

$Li = 7.$

Lithium occurs widely distributed in nature, but in small quantities. It is found in some mineral springs and in the ashes of many plants, chiefly that of tobacco and beet. It is usually obtained by separating it from its chloride by electrolysis. It is silver-white in color and

decomposes water at ordinary temperatures. It is the lightest of the solid elements and floats upon naphtha. Specific gravity, 0.589. It fuses at 180° C. (356° F.) and burns in air with an intense red light. Its salts closely resemble those of sodium.

Lithium chloride, LiCl, crystallizes at ordinary temperatures in regular, anhydrous octahedra; below 10° C. (50° F.), however, with two molecules of water. It is very deliquescent.

Lithium bromide, lithii bromidum (U. S. P.), LiBr, is obtained by decomposing lithium sulphate with potassium bromide, or by neutralizing a solution of hydrobromic acid with lithium carbonate. It crystallizes in deliquescent needles. Soluble in 0.6 part of water at 15° C. (59° F.) and 0.3 part of boiling water. Very soluble in alcohol and ether.

Lithium oxide, Li_2O, is a white solid formed by burning lithium in dry oxygen. It slowly dissolves in water, forming the hydroxide LiOH.

Lithium carbonate, lithii carbonas (U. S. P., Br.), Li_2CO_3, is obtained by fusing a native silicate called **lepidolite** with barium sulphate and carbonate and potassium sulphate. It is then extracted with water and precipitated with sodium carbonate. It is a white, odorless powder of a strongly alkaline taste, soluble in 80 parts of water at 15° C (59° F.), and in diluted acids with copious effervescence. It reacts readily with uric acid, forming a soluble lithium urate. This property renders it of value in preventing the deposit of uric acid in gout.

Lithii benzoas (U. S. P.), $LiC_7H_5O_2$, is a light, white powder having a faint benzoin-like odor and a sweetish taste. It is soluble in 4 parts of water and in 12 parts of alcohol. Its aqueous solution has a faintly acid reaction upon litmus paper.

Lithium citrate (U. S. P., Br.), $Li_3C_6H_5O_7$, is a white, odorless, deliquescent powder, readily soluble in water, almost insoluble in alcohol. It is made by double decomposition between Li_2CO_3 and citric acid.

$$3Li_2CO_3 + 2H_3C_6H_5O_7 = 2Li_3C_6H_5O_7 + 3CO_2 + 3H_2O.$$

Lithium salicylate (U. S. P.), $LiC_7H_5O_3$, is made by double decomposition between lithium carbonate and salicylic acid.

$$Li_2CO_3 + 2HC_7H_5O_3 = 2LiC_7H_5O_3 + CO_2 + H_2O.$$

A white, deliquescent, odorless powder having a sweetish taste. It is very soluble in water and alcohol.

SODIUM (Natrium).

$$Na = 23.$$

Occurrence.—This metal occurs widely distributed, being found in sea-water and in rock-salt, as the chloride, in many native silicates, and also as borax and Glauber's salt.

Preparation.—It was formerly obtained by a process which depends upon the reduction of the carbonate by carbon. An intimate mixture of the two substances was prepared by charring the tartrate of sodium in an iron retort. The temperature was then raised to redness, when the sodium was reduced, distilled off, and condensed in flattened receivers.

$$Na_2CO_3 + C_2 = Na_2 + 3CO.$$
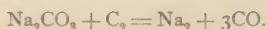
It is also manufactured by heating sodium hydroxide to about 800° C. (1472° F.) with iron carbide, when the sodium distils over and is condensed.

$$6NaOH + FeC_2 = 2Na_2CO_3 + Fe + 3H_2 + Na_2.$$
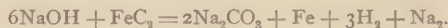
It is now generally prepared by the electrolytic decomposition of fused sodium hydroxide in the electrical furnace.

$$2NaOH = Na_2 + H_2 + O_2.$$
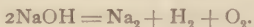
Properties.—Sodium is a soft, silver-white metal, resembling potassium, but less easily oxidized. On exposure to the air it becomes slowly coated with a brownish-yellow layer, and should be kept under naphtha. It fuses at 95.6° C. (204° F.), and volatilizes at a white heat, the vapor burning with a bright yellow flame. Specific gravity, 0.972. It is characterized by its affinity for oxygen, decomposing water at ordinary temperatures, liberating hydrogen, and forming sodium hydroxide, NaOH.

$$Na_2 + 2H_2O = 2NaOH + H_2.$$

Sodium chloride, common salt, sodii chloridum (U. S. P., Br.), NaCl, is found very abundant in nature. It is deposited, in the solid form, as rock-salt, in almost all parts of the globe. It is found, in solution, in all natural waters, and to the extent of 2.7 to 3.2 per cent. in sea-water. It also exists in most animal and vegetable tissues. It is formed in a great number of chemical reactions. Its most important source is the deposits of rock-salt, from which it is mined: it is also obtained by the evaporation of sea-water or saline spring-waters. It crystallizes from water in translucent cubes. It fuses at a

red heat and volatilizes at a white heat. Hot water dissolves but little more than cold: 100 parts of water at 0° C. (32° F.) dissolve 36 parts of the salt, and at 100° C. (212° F.) 39 parts. A saturated solution, therefore, contains thirty-six per cent. sodium chloride. The ice obtained from dilute solutions is nearly free from NaCl. On account of a slight admixture of magnesium salts, most specimens of common salt will deliquesce. The perfectly pure salt is not hygroscopic.

Sodium bromide, sodii bromidum (U. S. P., Br.), NaBr, is formed, together with sodium hypobromite, by the action of bromine upon a cold solution of sodium hydroxide. The hypobromite is converted into bromate upon evaporating the solution to dryness.

$$3Br_2 + 6NaOH = 5NaBr + NaBrO_3 + 3H_2O.$$

The mixture of NaBr and $NaBrO_3$ is then heated with charcoal, which converts the $NaBrO_3$ into NaBr.

$$5NaBr + NaBrO_3 + 3C = 6NaBr + 3CO.$$
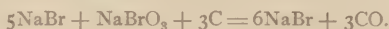
It crystallizes in anhydrous cubes, and is soluble in 1.13 parts of water at 20° C. (68° F.), and in 0.5 at 100° C. (212° F.). It contains 77.67 per cent. of bromine.

Sodium iodide, sodii iodidum (U. S. P., Br.), NaI, is made by the action of iodine upon a hot solution of sodium hydroxide.

$$3I_2 + 6NaOH = 5NaI + NaIO_3 + 3H_2O.$$
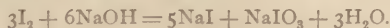
The solution is evaporated, and the salts are then heated in contact with charcoal, and the $NaIO_3$ reduced to NaI.

$$5NaI + NaIO_3 + 3C = 6NaI + 3CO.$$
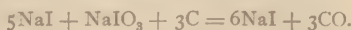
It crystallizes in cubes without water, and is soluble in 0.56 part of water at 20° C. (68° F.), and in 0.32 at 100° C. (212° F.). It contains 84.66 per cent. of iodine.

Oxides.—Two are known—Na_2O and Na_2O_2. The first of these is a white powder, formed by the oxidation of the metal in dry air. It is very deliquescent, soon liquefying in air. The peroxide, Na_2O_2, is a grayish-white mass, obtained by burning sodium in a current of oxygen. They both unite with water with great energy.

Sodium peroxide has recently come into use as a bleaching and oxidizing agent. It contains about twenty per cent. of available oxygen. When thrown into water, sodium hydroxide and oxygen are produced.

$$2Na_2O_2 + 2H_2O = 4NaOH + O_2.$$

20
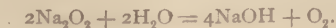
When thrown into a solution of a dilute acid, hydrogen dioxide is produced.

$$Na_2O_2 + 2HCl = 2NaCl + H_2O_2.$$

It is employed as an oxidizing agent in the laboratory, and occasionally in acid solutions as a disinfectant.

Sodium hydroxide, sodium hydrate, caustic soda, soda (U. S. P.), **soda caustica** (Br.), NaOH, is usually obtained by boiling a solution of sodium carbonate with calcium hydroxide.

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$
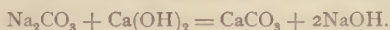
The resulting solution, after filtering, is evaporated to dryness, dissolved in alcohol, again evaporated, fused in a silver vessel, and cast into sticks. This product is usually labeled **caustic soda, by alcohol.** It is a white, opaque, brittle, crystalline mass, or in dry white pencils, fusing below redness; sp. gr., 2.00. It dissolves readily in water, the solution being known as **soda-lye** in the arts, and in pharmacy as **liquor sodæ** (sp. gr. of the latter, 1.059). This solution attacks glass; hence the necks and stoppers of bottles containing it should be coated with paraffin. When exposed in the air, sodium hydroxide attracts water and carbon dioxide, liquefies, and is converted into the carbonate.

Sodium sulphate, neutral sodium sulphate, Glauber's salt, sodii sulphas (U. S. P., Br.), $Na_2SO_4.10H_2O$, occurs native in deposits; also in solution in mineral waters. It is a by-product in the manufacture of sodium chloride from sea-water and brine, and in several manufacturing industries. It is prepared by the decomposition of common salt with sulphuric acid.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

Sodium sulphate crystallizes, at ordinary temperatures, with ten molecules of water, in large, colorless, monoclinic prisms, which effloresce in the air, losing all of their water. If heated to 33° C. (91.4° F.), they liquefy in their own water of crystallization, and at higher temperatures become anhydrous. At 12° C. (53.6° F.) crystals may be obtained having the formula $Na_2SO_4.7H_2O$.

The following curious action of the solution of Glauber's salt may also be noticed: If the solution, saturated at 33° C. (91.4° F.), be cooled down to the ordinary temperature, and even far below, no separation of crystals occurs, although the salt is very much less soluble at lower temperatures than at 33° C. (91.4° F.). This formation of a **supersaturated solution** is common to many salts, though not to so marked a degree as in the case of Glauber's salt. This supersaturated solution may be agitated, and still no crystals form. But, if it be gently touched with a glass rod or some other solid body, the entire mass will at once become crystallized.

Hydrogen sodium sulphate, acid sodium sulphate, sodium bisulphate, $NaHSO_4$, is obtained by the action of an excess of sulphuric acid upon sodium sulphate or sodium chloride.

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$
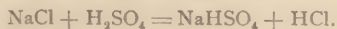
It crystallizes in long, four-sided prisms. It fuses readily, and at higher temperatures loses water and is converted into the pyrosulphate, $Na_2S_2O_7$. It is very soluble in water, giving an acid solution.

Sodium thiosulphate, sodium hyposulphite, $Na_2S_2O_3 \cdot 5H_2O$, is prepared by boiling the sulphite with sulphur.

$$Na_2SO_3 + S = Na_2S_2O_3.$$
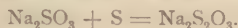
Sodium thiosulphate forms large monoclinic prisms, which contain five molecules of water, and is slightly deliquescent in the air. It is used as a reducing agent, decolorizing an iodine solution, with the formation of sulphuric acid and sodium iodide.

Sodium sulphite, sodii sulphis (U. S. P., Br.), $Na_2SO_3 \cdot 7H_2O$, is prepared by saturating one-half of a solution of Na_2CO_3 with sulphurous oxide, and adding the other half. The SO_2 converts the carbonate into the hydrogen sodium sulphite.

$$Na_2CO_3 + H_2O + 2SO_2 = 2NaHSO_3 + CO_2.$$
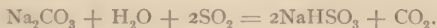
This salt reacts with sodium carbonate to produce the sulphite.

$$2HNaSO_3 + Na_2CO_3 = 2Na_2SO_3 + H_2O + CO_2.$$
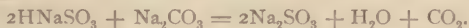
Sodium bisulphite, sodii bisulphis (U. S. P.), $HNaSO_3$, is made by saturating a solution of sodium carbonate with SO_2, evaporating and crystallizing.

Sodium carbonate, soda, neutral carbonate of soda, sal soda, washing soda, sodii carbonas (U. S. P., Br.), $Na_2CO_3 \cdot 10H_2O$, is the most important of the sodium compounds for industrial purposes. It occurs abundantly in nature, in the so-called sodium seas (in Egypt, and the Caspian Sea), and is contained in the ashes of many sea-plants, chiefly the algæ. The principal supply is sodium chloride, from which it is manufactured according to a method devised by Leblanc in 1808. By this method the sodium chloride is first converted into the sulphate by warming with sulphuric acid.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

This part of the process is called the **salt cake process.** The sulphate, when dried, is mixed with charcoal and calcium carbonate,

and strongly heated. Two reactions take place during this process : **First,** the carbon reduces the sodium sulphate to sulphide.

$$Na_2SO_4 + C_2 = Na_2S + 2CO_2.$$

Second, the sodium sulphide and calcium carbonate react to form calcium sulphide and sodium carbonate. This is known as the **soda ash process.**

$$Na_2S + CaCO_3 = CaS + Na_2CO_3.$$

The high temperature also converts a portion of the calcium carbonate into calcium oxide and carbon dioxide. The products of this fusion, known as **black ball soda,** are, therefore, sodium carbonate, calcium sulphide, and calcium oxide. The black ball is broken up and lixiviated with hot water, which dissolves out the sodium carbonate ; this solution is evaporated, and crude **soda ash,** or **soda** of commerce, results.

Of late years another process, known as Solvay's, or the ammonia method, has largely replaced that of Leblanc. In this process a strong solution of sodium chloride is treated at the same time with ammonia gas and carbon dioxide,

$$NaCl + NH_3 + CO_2 + H_2O = NaHCO_3 + NH_4Cl,$$

forming the sparingly soluble sodium bicarbonate and the freely soluble ammonium chloride. The sodium bicarbonate, which crystallizes out, is then converted into the carbonate by heat. The carbonate is also largely made by the **cryolite process.** Cryolite is a mineral found in great abundance in Greenland. It is a double fluoride of aluminum and sodium $(NaF)_6.Al_2F_6$.

This is heated with lime, CaO, which decomposes it, forming calcium fluoride and aluminate of sodium.

$$(NaF)_6.Al_2F_6 + 6CaO = 6CaF_2 + (Na_2O)_3.Al_2O_3.$$
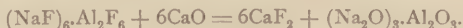
The aluminate of sodium is then dissolved out with water and carbon dioxide passed through the solution.

$$(Na_2O)_3.Al_2O_3 + 3H_2O + 3CO_2 = 3Na_2CO_3 + Al_2(OH)_6.$$

The $Al_2(OH)_6$ is insoluble and separates, while the sodium carbonate solution is evaporated and crystallized.

At ordinary temperatures sodium carbonate crystallizes in large rhombic crystals containing ten molecules of water, which effloresce in dry air. It is soluble in water most freely at 38° C. (100.4° F.). Its solutions have an alkaline reaction. When the crystals are calcined at a dull red heat they disintegrate, give off their water of crystalliza-

tion, and form a white powder, the **sodii carbonas exsiccata** of the U. S. P., Br. One hundred parts of H_2O dissolve 10 parts of this anhydrous carbonate at $0°$ C. ($32°$ F.), and 138 parts at $38°$ C. ($100.4°$ F.).

Hydrogen sodium carbonate, acid sodium carbonate, sodium bicarbonate, sodii bicarbonas (U. S. P., Br.), $NaHCO_3$, is found in many mineral waters. It is produced by the ammonia process described above, and by the action of carbon dioxide upon sodium carbonate.

$$Na_2CO_3 + CO_2 + H_2O = 2NaHCO_3.$$

It forms small, rectangular prisms, which are anhydrous, but dissolve in ten or eleven parts of water. Its solutions are nearly neutral to test-paper. By heating the solid, or boiling its solutions, it gives off carbon dioxide and is converted into the carbonate.

Sodium Phosphates.—These are three in number. They are less soluble and crystallize more easily than the potassium salts of phosphoric acid.

The **tri-sodium** phosphate, or **basic** phosphate, $Na_3PO_4.12H_2O$, is made by saturating one molecule of phosphoric acid with three molecules of sodium hydroxide. It crystallizes in six-sided prisms, and is soluble in 5.1 parts of water at $15.5°$ C. ($59.9°$ F.). Its solution is alkaline to test-paper.

Hydrogen disodium phosphate, disodium phosphate, neutral sodium phosphate, sodii phosphas (U. S. P., Br.), $Na_2HPO_4.12H_2O$, is more stable than the other phosphates, and is the one generally employed in medicine and in laboratories. It may be prepared by treating phosphoric acid with sodium hydroxide to feeble alkaline reaction. Below $30°$ C. ($86°$ F.) it crystallizes in large, rhombic prisms with 12 aq.; at $33°$ C. ($91.4°$ F.) it crystallizes with 7 aq. The salt with 12 aq. effloresces in air, losing 5 aq.; that with 7 aq. does not. Both are freely soluble in water and show a faintly alkaline reaction.

Monosodium phosphate, acid sodium phosphate, $NaH_2PO_4.-H_2O$, crystallizes in rhombic prisms with one molecule of water and is acid in reaction. At $100°$ C. ($212°$ F.) it loses its water of crystallization, and at about $250°$ C. ($482°$ F.) forms **sodium pyrophosphate, sodii pyrophosphas** (U. S. P.), $Na_4P_2O_7.10H_2O$. It occurs as colorless, translucent prisms, permanent in the air, and having a slightly alkaline reaction. It is soluble in twelve parts of water and insoluble in alcohol. When NaH_2PO_4 is heated to a bright red heat the **metaphosphate,** $NaPO_3$, is formed.

$$NaH_2PO_4 = NaPO_3 + H_2O.$$
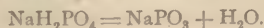
Sodium nitrate, Chili saltpeter, sodii nitras (U. S. P., Br.), $NaNO_3$, is found native in extensive deposits in Peru and Chili. It crystallizes in rhombohedra, which closely resemble cubes; hence, it is called cubic saltpeter. It is deliquescent, and is, therefore, not adapted for the manufacture of gunpowder. It has a cooling, saline, somewhat bitter taste. It is more readily soluble in water than potassium nitrate, which, in other respects, it quite closely resembles. It is used in the manufacture of nitric acid, and also as a fertilizer.

Sodium Borates.—Six are known. The only one of importance is the **disodium tetraborate, sodium pyroborate, borax, tincal, sodii boras** (U. S. P., Br.), $Na_2B_4O_7.10H_2O$, which is found native in some of the lakes of Thibet, from which country it was formerly imported. The principal source now is the borax lake in California.

It may be prepared artificially by boiling boric acid with sodium carbonate. Boric acid is found in the lagoons of Tuscany. This is its present source. Borax crystallizes in large, hexagonal prisms, with ten molecules of H_2O, or in regular octahedra with $5H_2O$. The former variety effloresces in dry air; the latter is permanent. Both dissolve in sixteen parts of cold and 0.5 part of boiling water, forming a solution that has a feebly alkaline reaction. Upon heating, both salts puff up considerably, lose their water, and form a white, porous mass (**burned borax**), which finally fuses to a transparent glass. In the fused state it will dissolve many metallic oxides, forming clear glasses, which often show a characteristic color on cooling; thus, copper oxide gives a blue and chromic oxide an emerald-green glass. Borax is used in this way as a blowpipe test for certain metals.

It is this property of dissolving oxides of the metals that renders borax useful in welding and soldering metals. In these operations it is used to remove the oxide, or rust, from the surfaces of the metals to be united.

Sodium Hypochlorite.—$NaClO$. An aqueous solution of this salt is known as **liquor sodæ chloratæ** (U. S. P., Br.), **Labarraque's solution.** It may be prepared by decomposing a solution of chlorinated lime with sodium carbonate.

$$CaO_2Cl_2 + CaCl_2 + 2Na_2CO_3 = 2NaCl + 2NaClO + 2CaCO_3.$$

The official solution contains sodium hypochlorite, sodium chloride, and sodium carbonate.

To make a liter of the solution, 75 gm. of chlorinated lime are triturated well with about 400 c.c. of water, the solution filtered, and the residue washed with 100 c.c. of cold water. To this solution is then added a solution of 150 gm. of sodium carbonate in 300 c.c. of hot water. The turbid mixture may then be filtered, or set aside to

allow the $CaCO_3$ to settle, and the clear, supernatant liquid decanted off. The solution should be kept in well-stoppered bottles, and protected from the light to prevent too rapid deterioration. It should contain 2.6 per cent. by weight of available chlorine. It yields up its chlorine readily, thus acting as an efficient disinfecting and deodorizing agent.

Sodium chlorate, sodii chloras (U. S. P.), $NaClO_3$, may be made by a double decomposition between $KClO_3$ and sodium bitartrate, $NaHC_4H_4O_6$, forming cream of tartar, $KHC_4H_4O_6$, and $NaClO_3$.

Sodii benzoas (U. S. P., Br.), $NaC_7H_5O_2$, is made by adding benzoic acid to a solution of sodium bicarbonate as long as effervescence continues.

$$HC_7H_5O_2 + NaHCO_3 = NaC_7H_5O_2 + CO_2 + H_2O.$$

It is a white powder, having a very faint, benzoin-like odor, and a sweet astringent taste. It is used as an antifermentative agent.

Sodii arsenas (U. S. P., Br.), $Na_2HAsO_4.7H_2O$, is made by heating to fusion arsenous acid, with exsiccated sodium carbonate and sodium nitrate. Pyroarsenate of sodium is formed, which is converted into sodium arsenate when dissolved in water.

Sodii Sulphocarbolas (U. S. P., Br.).—$NaSO_3C_6H_4OH$. When crystallized carbolic acid is dissolved in strong sulphuric acid, sulphocarbolic acid is formed. When this is treated with barium carbonate, sulphocarbolate of barium is formed in solution. If this solution is now treated with sodium sulphate, a precipitate of barium sulphate will form, and sulphocarbolate of sodium may be crystallized out from the solution.

Sodii acetas (U. S. P.), $NaC_2H_3O_2.3H_2O$, may be made by neutralizing acetic acid with bicarbonate of sodium.

$$NaHCO_3 + HC_2H_3O_2 = NaC_2H_3O_2 + CO_2 + H_2O.$$
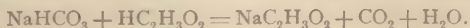
Physiological Effects of the Sodium and Potassium Compounds.—The action of the halogen salts of these metals is generally that of the combined chlorine, bromine, or iodine. The hydroxides of both metals, and, to a lesser degree, the carbonates, tend to disintegrate the tissues with which they come in contact; hence, they possess powerful caustic properties. If taken internally, the hydroxides are highly poisonous, causing death, like the mineral acids, either immediately by their corrosive properties, or, secondarily, by exciting inflammation of the gastro-intestinal mucous membrane, with consequent thickening and constriction.

In cases of poisoning by the caustic alkalies, the stomach should be evacuated, and a weak acid, such as diluted vinegar or lemon juice, given to neutralize the

alkali; or, it should be saponified by the administration of some oil or fat. The nitrate of these metals is toxic in large doses, and for it there is no direct antidote. The alkaline carbonates are, undoubtedly, of considerable importance to the carrying on of the normal functions of the animal body. In the first place, it is exceedingly probable that some, at least, of the albuminoid matters of the blood are held in solution by reason of its alkaline reaction, which is largely given to it by these carbonates.

Secondly, it has been shown very clearly that the alkaline reaction of the blood is of first importance to the oxidation processes, which are intimately connected with the production of animal heat and retrograde metamorphosis. It is only in the presence of a free alkali that many organic substances will unite with oxygen, and thus their decomposition at the temperature of the body without an alkali would be impossible. In proof of this, it is known that, if the free vegetable acids are given, they will reappear in the urine, for the most part, unchanged; but if they are in combination with the alkalies when given, they are thoroughly burned up in the blood, and reappear as carbonates. In fact, so important are these alkaline salts— carbonates and phosphates—that without them albuminoid bodies will not support life.

The alkaline carbonates, when taken in sufficient quantity, render the urine alkaline in reaction and increase the quantity. The tartrates, citrates, and acetates of sodium and potassium have a similar action upon the economy to that of the carbonates, into which they are converted either in the intestines or the blood. A slightly more cathartic action is attributed to the tartrates than is possessed by the carbonates. This action is also more or less shown by the sulphates and phosphates.

POTASSIUM (Kalium).

$$K = 39.$$

Occurrence.—This metal is found, principally as silicates, widely distributed in rocks and minerals. By the action of the atmosphere and other influences, these silicates gradually decompose, the potassium passes into the soil and is absorbed by the plants, from the ashes of which it may be obtained. The chloride and sulphate are also found in sea-water, and in large deposits, mixed with other chlorides. **Sylvite**, KCl, and **carnallite**, $KCl.MgCl_2.6H_2O$, are mined in Stassfurt, Germany, as a source of potassium salts.

Preparation and Properties.—It is prepared by calcining an intimate mixture of the carbonate with carbon.

$$K_2CO_3 + C_2 = K_2 + 3CO.$$

Such a mixture may be made by heating organic potassium salts, as crude tartar, to redness. In this way a black mass is formed, consisting of potassium carbonate and free carbon. By heating this black mass

to a white heat in an iron retort, the potassium distils off, and is condensed under mineral naphtha. It is now generally prepared by heating to a white heat a mixture of KOH with metallic iron:

$$4KOH + 3Fe = Fe_3O_4 + 2H_2 + 2K_2.$$
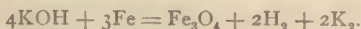
Or by subjecting fused KOH to a strong electrical current in the electrical furnace, which liberates the potassium and hydrogen at the negative pole and the oxygen at the positive pole:

$$2KOH = K_2 + H_2 + O_2.$$
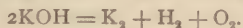
This method has been perfected by Castner and made available as a manufacturing process.

Potassium is a silver-white, lustrous metal, brittle at $0°$ C. ($32°$ F.), waxy at $15°$ C. ($59°$ F.). fuses at $62°$ C. ($143.6°$ F.), and distils at a red heat. Specific gravity at $15°$ C. ($59°$ F.) $= 0.865$. Its affinity for oxygen is such that, if it be exposed to the air, it tarnishes at once. It decomposes water or ice with great energy, with the formation of potassium hydroxide and the liberation of hydrogen, which is ignited by the high temperature caused by the reaction. It combines directly and energetically with the halogens, sulphur, phosphorus, arsenic, antimony, and tin

The **haloid salts** of potassium may be formed by direct union of the haloids with the metal, or by saturating the hydroxide or carbonate with one of the haloid acids. They all have a bitter, salty taste, are freely soluble in water, and crystallize in cubes. They fuse easily, and are somewhat volatile at high temperatures.

Potassium chloride, KCl, occurs native, either pure or mixed with other chlorides. At Stassfurt it is found in large deposits, as **sylvite** and **carnallite**, which deposits form the chief source of the potassium compounds.

The chloride crystallizes in anhydrous cubes, of sp. gr. 1.84, closely resembling common salt. One hundred parts of water dissolve 30 parts at $0°$ C. ($32°$ F.), and 0.2738 part more for every degree of increase in temperature.

Potassium bromide, potassii bromidum (U. S. P., Br.), KBr, is generally obtained by dissolving bromine in a solution of potassium hydroxide; the bromate also produced in the reaction is converted into bromide by calcining the product with charcoal.

$$3Br_2 + 6KOH = 5KBr + KBrO_3 + 3H_2O.$$
$$5KBr + KBrO_3 + C_3 = 6KBr + 3CO.$$
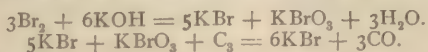
It may also be prepared by acting upon ferrous bromide with potassium carbonate.

$$FeBr_2 + K_2CO_3 = FeCO_3 + 2KBr.$$

It has the general properties of the other haloid salts, and is used in photography and in medicine.

Potassium iodide, potassii iodidum (U. S. P., Br.), KI, may be prepared, like the preceding, by using iodine instead of bromine, or by using ferrous iodide instead of bromide. It crystallizes in large, white, translucent cubes, salty in taste and permanent in the air. It dissolves to the extent of 100 parts in 73.5 parts of water at ordinary temperatures. Its aqueous solution dissolves iodine in large quantities, forming the **liquor iodi compositus** (U. S. P., Br.). It also dissolves many other metallic iodides, to form double iodides. Its medicinal effects are those of iodine. When employed in chronic poisoning by lead or mercury, it is supposed to unite with the metals in the blood or tissues to form soluble iodides, and thus pass them out by the urine.

Unguentum iodi (U. S. P., Br.) contains 4 gm. iodine and 1 gm. KI to 100 of ointment. **Ung. potassii iodidi** (U. S. P., Br.) contains twelve per cent. of KI.

Potassium Fluoride.—KF. Its aqueous solution attacks glass. Is not of much importance to the medical or pharmaceutical student.

Potassium cyanide, potassii cyanidum (U. S. P., Br.), KCN, may be obtained either by saturating potassium hydroxide with hydrocyanic acid or by heating potassium ferrocyanide. It is a white, amorphous, deliquescent mass, easily fusible, and smelling of cyanogen. Its solution is very poisonous. Its effects upon the economy are uncertain, but are probably those of hydrocyanic acid. In case of poisoning by it, the stomach should be evacuated and the antidotes of hydrocyanic acid given.

Ferrocyanide and ferricyanide will be found on page 221.

Potassium and Oxygen.—**Potassium oxide**, K_2O. results from the direct oxidation of potassium, by simply exposing thin strips of the metal to dry air, or by the action of potassium upon the hydroxide.

$$2KOH + K_2 = 2K_2O + H_2.$$
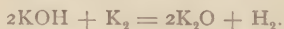
It is a white, deliquescent, caustic powder, uniting readily with water to form the hydroxide.

Potassium hydroxide, potassium hydrate, caustic potash, potassa (U. S. P.), **potassa caustica** (Br.), KOH, is prepared by the reaction of potassium carbonate upon calcium hydroxide (slaked lime).

$$K_2CO_3 + Ca(OH)_2 = CaCO_3 + 2KOH.$$
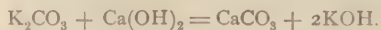
After these substances have been boiled together, the precipitate is allowed to settle. The clear liquid is then poured off, evaporated,

and the residue fused in a silver dish. The fused mass is then cast into sticks. This is called **potash by lime,** and is not pure. To render it purer it is dissolved in alcohol, the solution evaporated to dryness, the residue again melted and cast in silver molds. This product is **potash by alcohol,** and is nearly free from the chloride and other potassium salts. It is a white, opaque, brittle solid, usually met with in the form of cylindrical sticks, but sometimes in lumps. It has a sp. gr. of 2.1. It fuses quite easily, and, at high temperatures, volatilizes undecomposed. It is freely soluble in water; less so in alcohol. The solutions have a marked alkaline reaction, saponify fats, and are strongly caustic. When exposed to the air it absorbs water and carbon dioxide, and is changed into the carbonate. Its watery solution is largely used as a reagent in chemical analysis. It dissolves chlorine, bromine, iodine, sulphur, and phosphorus. It decomposes the ammoniacal salts, liberating ammonia; it also decomposes the salts of many of the metals, with the formation of a potassium salt and a hydroxide or oxide of the metal.

Potassa cum calce (U. S. P.) is made by rubbing together, in an iron mortar, lime and potassa to form a powder. It is to be kept in a well-stoppered bottle. It is used as a caustic.

Liquor potassæ is a five per cent. aqueous solution of potassium hydroxide.

Potassium Chlorate, Potassii Chloras (U. S. P., Br.).— $KClO_3$. When a hot, concentrated solution of potassium hydroxide is treated with chlorine gas, the following reaction occurs: •

$$6KOH + 3Cl_2 = 5KCl + KClO_3 + 3H_2O.$$

It is usually made by the action of chlorine upon a mixture of calcium hydroxide and potassium chloride. By this method a double reaction takes place. Calcium chlorate is first formed.

$$6Ca(OH)_2 + 6Cl_2 = 5CaCl_2 + Ca(ClO_3)_2 + 6H_2O.$$
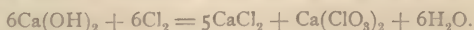
This then reacts with the potassium chloride as follows:

$$Ca(ClO_3)_2 + 2KCl = 2KClO_3 + CaCl_2.$$
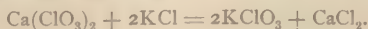
The hot solution is rapidly evaporated and the residue purified by recrystallization. It crystallizes in shining, transparent plates of the monoclinic system. Soluble in 16.7 parts of water at 15° C. (59° F.); soluble with difficulty in alcohol. It is cooling and astringent to the taste, fuses at 234° C. (435° F.), and above 352° C. (665.6° F.) it is decomposed, giving up a portion of its oxygen and changing to the **perchlorate,** $KClO_4$, which at higher temperatures decomposes into

oxygen and potassium chloride.   As it gives up oxygen easily, it serves
as a valuable oxidizing agent and as a means of preparing this gas.
Mixed with readily oxidizable substances, as carbon, sulphur, phos-
phorus, sugar, tannin, resins, etc., the mixtures explode when heated
or subjected to a sudden shock.   The igniting material with which
parlor-matches are tipped consists of antimony sulphide and potassium
chlorate.   When rubbed upon a surface coated with red phosphorus
they ignite.

   Potassium hypochlorite, liq. potassæ chloratæ (N. F.),
$KClO$, is formed by the action of chlorinated lime upon a cold solution
of potassium carbonate.

   It can only be obtained in aqueous solutions.   If the solution be
evaporated, the salt splits up into chloride and chlorate.

$$3KClO = 2KCl + KClO_3.$$

When treated with acids, it yields free chlorine and bleaches strongly.
The ordinary solutions used in bleaching are solutions of potassium
hypochlorite and chloride, and are known as **Javelle water.**

   Potassium nitrate, niter, saltpeter, potassii nitras (U. S. P.,
Br.), KNO_3, exists native, and is produced artificially whenever nitrog-
enous organic substances decay in the presence of potassium carbon-
ate.   Upon the so-called saltpeter plantations, manures and various
animal refuse are arranged in layers, with wood-ashes and lime, in large
heaps, and submitted to the action of the air and moisture for two or
three years, whereby, from the slow oxidation of the nitrogen under
the influence of nitrifying organisms, nitrates of potassium and calcium
are produced.   The contents of the heaps are then lixiviated with
water, which dissolves the potassium and calcium nitrates.   Potassium
carbonate is added to the solution to convert the last salt into potassium
nitrate.

$$Ca(NO_3)_2 + K_2CO_3 = CaCO_3 + 2KNO_3.$$

The calcium carbonate is filtered off and the solution evaporated and
allowed to crystallize.   Another method, and probably the one most
frequently employed at present, consists in the decomposition of
sodium nitrate (Chili saltpeter) by means of potassium carbonate
or chloride.

$$NaNO_3 + KCl = NaCl + KNO_3.$$

It crystallizes in large, six-sided, rhombic prisms.   One hundred parts
of water dissolve 244 parts of the salt at 100° C. (212° F.), but at 0°
C. (32° F.) only 13 parts.   It fuses at 353° C. (667° F.).   Below
a red heat it decomposes into oxygen and potassium nitrite, KNO_2.

   The readiness with which it gives up its oxygen, when heated in the

presence of an oxidizable substance, makes it a valuable oxidizing agent.

Gunpowder is a granular mixture of potassium nitrate, sulphur, and charcoal in such proportion that the nitrate contains all the oxygen necessary for the combustion of the sulphur and charcoal. The following equation expresses approximately the decomposition caused by the burning of powder:

$$2KNO_3 + S + 3C = K_2S + 3CO_2 + N_2.$$

The effect produced, therefore, depends upon the disengagement of carbon dioxide and nitrogen, the volume of which gases is almost 100 times greater than that of the powder. The heat of the combustion further expands the gases at the time of the explosion.

Potassium carbonate, salt of tartar, pearlash, potassii carbonas (U. S. P., Br.), K_2CO_3, exists in mineral waters, in the animal economy, and as the principal ingredient of wood-ashes. Plants absorb potassium salts from the earth and convert them into salts of the organic acids. When the plants are burned the organic acids are destroyed and potassium carbonate is produced, which is obtained by the lixiviation of the ashes and evaporation. This method is not much employed at present. The immense deposits in Stassfurt and Galicia afford an almost inexhaustible supply of potassium salts. It occurs commercially as a white, granular, deliquescent powder, freely soluble in water, the solution having a caustic taste and an alkaline reaction.

Potassium carbonate is largely made from the native chloride by the Leblanc process. A very pure potassium carbonate is made from argols (impure bitartrate of potassium) by calcination.

$$2KHC_4H_4O_6 + 5O_2 = K_2CO_3 + 7CO_2 + 5H_2O.$$
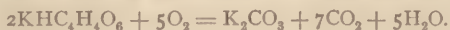
Potassium Bicarbonate, Hydropotassium Carbonate, Potassii Bicarbonas (U. S. P., Br.).—$KHCO_3$. When carbon dioxide is passed through a concentrated solution of potassium carbonate, it is absorbed and potassium bicarbonate is produced.

$$K_2CO_3 + H_2O + CO_2 = 2KHCO_3.$$

This salt crystallizes in oblique, rhombic prisms of the monoclinic system. It dissolves in three to four parts of water: the solution is faintly alkaline, but not caustic. The substance that is still extensively used in some parts of the country in baking, under the name of **saleratus**, is this, or the corresponding sodium salt. It "raises" the bread by the action of heat in setting free the carbon dioxide and leaving potassium (or sodium) carbonate, which, by its strongly alkaline reaction, may cause digestive disturbances.

Sulphides.—Five are known : K_2S, K_2S_2, K_2S_3, K_2S_4, and K_2S_5; also a sulphydrate, KSH. The latter is prepared by the action of hydrogen sulphide upon potassium hydroxide.

$$KOH + H_2S = KSH + H_2O.$$

The **pentasulphide, liver of sulphur, potassa sulphurata** (U. S. P., Br.), K_2S_5, is obtained by fusing potassium carbonate with an excess of sulphur. It decomposes readily, and when treated with mineral acids it gives off hydrogen sulphide. It is a liver-brown solid, becoming lighter on the surface. It has an alkaline, acrid taste, and gives off H_2S.

Potassium sulphate, dipotassium sulphate, potassii sulphas (U. S. P., Br.), K_2SO_4, is found in the Stassfurt mines, in plant-ashes, and in solution in mineral waters. It is obtained by the action of sulphuric acid upon potassium chloride, as a by-product in some chemical manufacturing processes.

$$2KCl + H_2SO_4 = K_2SO_4 + 2HCl.$$

It crystallizes without water in small, rhombic prisms, of a bitter, salty taste, and is soluble in ten parts of water at ordinary temperatures.

Hydropotassium sulphate, acid potassium sulphate, potassium bisulphate, $KHSO_4$, is formed as a by-product in the manufacture of nitric acid from potassium nitrate; crystallizes in large, rhombic plates, and is very readily soluble in water. At about 200° C. (392° F.) it fuses, loses water, and is converted into the pyrosulphate, $K_2S_2O_7$.

Sulphites.—Three are known : K_2SO_3, $KHSO_3$, and $K_3S_2O_5$.

Potassium sulphite, neutral potassium sulphite, K_2SO_3. This salt crystallizes in oblique rhombic octahedra, which dissolve readily in water and have a sulphurous odor. When its solution is exposed to the air, it absorbs oxygen, and the salt is converted into the sulphate.

Potassium acetate, potassii acetas (U. S. P., Br.), $KC_2H_3O_2$, exists in the juices of plants. It is obtained by neutralizing acetic acid with potassium carbonate or bicarbonate. It crystallizes in shining needles, is deliquescent, and very soluble in water.

Oxalates.—Three are known to exist: **Potassium oxalate, neutral oxalate,** $K_2C_2O_4.Aq.$, formed by saturating oxalic acid with potassium carbonate. **Hydropotassium oxalate, monopotassium oxalate, binoxalate of potash,** KHC_2O_4. **Potassium quadroxalate,** $KHC_2O_4.C_2O_4H_2.2$ Aq. A mixture of these last two salts is known as **salt of lemon, or salt of sorrel,** and is used for bleaching straw and to remove ink-stains. In appearance it closely resembles Epsom salt, and has caused many cases of oxalic acid poisoning by being taken by mistake for that salt.

Tartrates.—**Potassium tartrate, soluble tartar, neutral tartrate of potash, potassii tartras** (Br.), $K_2C_4H_4O_6$, is a white crystalline powder, very soluble in water; soluble in 240 parts of alcohol. **Hydropotassium tartrate, cream of**

tartar, potassii bitartras (U. S. P.), potassii tartras acida (Br.), $KHC_4H_4O_6$. A brown red, crystalline crust is obtained from the bottoms and sides of wine casks after fermentation has taken place. This is known in commerce as argol, or crude tartar, and is composed in great part of potassium bitartrate, with tartrate of lime and coloring matter.

To extract the cream of tartar, the argol is boiled with water or heated in a closed digester by superheated steam. The latter process renders the calcium tartrate insoluble and separates it almost completely from the cream of tartar, which goes into solution. The solution thus obtained is allowed to cool and crystallize; the crystals are redissolved in hot water, treated with animal charcoal to remove coloring matters, filtered, and again crystallized. The product of this process is almost chemically pure acid potassium tartrate.

It crystallizes in hard, opaque, rhombic prisms, very sparingly soluble in water, still less so in alcohol. Its solution is acid to the taste and to litmus paper. It is largely used in baking, combined with sodium bicarbonate, the two substances reacting upon each other to form Rochelle salt, with the liberation of carbon dioxide. Baking powders are extensively used at present, instead of yeast, for raising cake, biscuits, etc. In all of them the action depends upon the decomposition of sodium bicarbonate by some salt having an acid reaction or by a weak acid.

In addition to the bicarbonate, and the starch added to preserve them, many of them contain either tartaric acid, alum, or acid phosphate of calcium, instead of cream of tartar.

Some of the reactions that take place in baking powders, to set free carbon dioxide, are the following:

1. $KHC_4H_4O_6 + NaHCO_3 = NaKC_4H_4O_6 + H_2O + CO_2$.
       Potassium   Sodium   Sodio-potassium   Water.   Carbon.
       Bitartrate.   Bicarbonate.   Tartrate.   Dioxide.

2. $Al_2(SO_4)_3.K_2SO_4 + 6NaHCO_3 = K_2SO_4 + 3Na_2SO_4 + Al_2H_6O_6 + 6CO_2$.
   Aluminium Potassium   Sodium   Potassium   Sodium   Aluminium   Carbon
      Alum.   Bicarbonate.   Sulphate.   Sulphate.   Hydroxide.   Dioxide.

3. $CaH_4(PO_4)_2 + 2NaHCO_3 = CaHPO_4 + Na_2HPO_4 + 2H_2O + 2CO_2$.
     Calcium   Sodium   Hydro-calcium   Sodium   Water.   Carbon
   Biphosphate.   Bicarbonate.   Phosphate.   Phosphate.   Dioxide.

A good powder may be made by intimately mixing two parts of cream of tartar with one of sodium bicarbonate, and adding a little flour or starch.

Sodium potassium tartrate, Rochelle salt, potassii et sodii tartras (U. S. P.), $NaKC_4H_4O_6.4H_2O$, is prepared by boiling acid potassium tartrate with sodium carbonate.

$$2KHC_4H_4O_6 + Na_2CO_3 = 2KNaC_4H_4O_6 + CO_2 + H_2O.$$
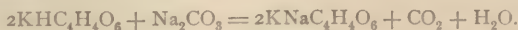
It forms large, transparent, prismatic, slightly efflorescent crystals, soluble in 1.4 parts of cold water; saline and slightly bitter to the taste, and neutral in reaction.

Potassium antimonyl tartrate, tartrated antimony, tartar emetic, antimonii et potassii tartras (U. S. P.), $(SbOKC_4H_4O_6).H_2O$, is prepared by boiling a solution of cream of tartar with antimonous oxide.

$$2HKC_4H_4O_6 + Sb_2O_3 = 2(SbO)KC_4H_4O_6 + H_2O.$$
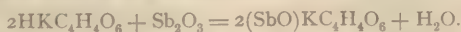
Its crystals are transparent, right rhombic octahedra, efflorescing in the air. It is quite soluble in water, the solution having a nauseating, metallic taste. It is poisonous, and has even caused death when applied to the skin as a local irritant and vesicant.

RUBIDIUM and CESIUM.

Rb = 85.3.　　　　　　Cs = 132.6.

These rare metals were discovered in 1860 by Bunsen and Kirchoff, by means of the spectroscope. Both elements were named from the color of their lines in the spectrum (**rubidius**, dark red, and **cæsius**, sky blue). They occur in small quantities, widely distributed, often accompanying potassium. With platinum chloride they form double chlorides, $PtCl_4.2RbCl$. Rubidium iodide and rubidium ammonium bromide have been used in medicine.

Rubidium iodide, RbI, occurs as colorless crystals, readily soluble in water, and having most of the physical properties of potassium iodide, for which it is substituted as a remedy, in doses of two grains three times daily.

Rubidium ammonium bromide, $RbBr.3NH_4Br$, occurs as a white crystalline powder, readily soluble in water and possessing a cooling, saline taste. It has been used in epilepsy.

AMMONIUM COMPOUNDS.

Ammonium.—NH_4. This radical has only a hypothetical existence, never having been isolated. But there are many reasons for believing that it does actually exist in combination in the ammonium compounds, and that in these compounds it plays the rôle of a metal resembling sodium and potassium. The oxide of this radical has not been separated, but the hydroxide is well known.

Ammonium chloride, ammonium muriate, sal ammoniac, ammonii chloridum (U. S. P., Br.), NH_4Cl, was formerly obtained by the dry distillation of camels' dung. At present it is prepared chiefly by saturating the **ammonia liquor** from gas-works with hydrochloric acid, evaporating the solution to dryness, and subliming the residue in iron vessels. Prepared in this way, it is a compact, tough, fibrous mass, which dissolves in 2.7 parts cold and one part boiling water. It crystallizes from its solution in small octahedra or cubes, of a sharp, salty taste, and a neutral reaction. When heated, it volatilizes without fusing; at the same time a dissociation into NH_3 and HCl occurs, but, on cooling, these products recombine into ammonium chloride.

This salt exists in minute quantities in the gastric juice of various animals. The urine, saliva, and tears also contain some ammonium compound, which is said to be the chloride.

Ammonium bromide, ammonii bromidum (U. S. P., Br.), $(NH_4)Br$, may be prepared by direct combination of ammonia and hydrobromic acid, or by decomposing ferrous bromide with ammonium hydroxide,

$$FeBr_2 + 2NH_4OH = Fe(OH)_2 + 2NH_4Br,$$
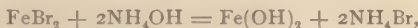
or by subliming a mixture of potassium bromide and ammonium sulphate.

$$2KBr + (NH_4)_2SO_4 = 2NH_4Br + K_2SO_4.$$

It forms a white, crystalline powder, or large prisms, which turn yellow on exposure to the air, and possess a saline, pungent taste and neutral reaction. It dissolves in 1.5 parts of water, and volatilizes without decomposition.

Ammonium iodide, ammonii iodidum (U. S. P.), $(NH_4)I$, is prepared by the action of hydriodic acid upon ammonia, or by the double decomposition of potassium iodide and ammonium sulphate.

$$2KI + (NH_4)_2SO_4 = 2NH_4I + K_2SO_4.$$

It may also be prepared by adding ammonia water to a solution of ferrous iodide.

$$FeI_2 + 2NH_4OH = Fe(OH)_2 + 2NH_4I.$$
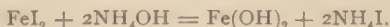
It forms cubic crystals, which are deliquescent and soluble in 0.6 part of water. They decompose in the air, turning yellow and emitting the odor of iodine. **Tinctura iodi decolorata,** or colorless tincture of iodine, is prepared by mixing equal volumes of compound tincture of iodine and strong ammonia water. It is essentially a solution of NH_4I and KI in alcohol and ammonia water.

Ammonium hydroxide, NH_4OH, is believed to exist in solution in the ordinary aqua ammoniæ, although, when the attempt is made to isolate it, decomposition ensues. (See p. 174.) It is made by warming ammonium chloride or sulphate with calcium hydroxide.

Aqua ammoniæ fortior (U. S. P.) and **aqua ammoniæ** (U. S. P.) have been described elsewhere.

Ammonium Carbonates.—Three are known. **Ammonium carbonate, neutral ammonium carbonate,** $(NH_4)_2CO_3$, may be prepared as a crystalline powder by passing ammonia-gas through a concentrated solution of the sesquicarbonate. Exposed to the air, it splits up into ammonia and the acid carbonate, NH_4HCO_3.

$$(NH_4)_2CO_3 = NH_4HCO_3 + NH_3.$$

Hydro-ammonium carbonate, acid ammonium carbonate, NH_4HCO_3, is obtained when a solution of ammonium hydroxide or

sesquicarbonate is saturated with carbon dioxide. It forms large, rhombic crystals, which are quite soluble in water. At 60° C. (140° F.) it is decomposed into ammonia and carbon dioxide.

Ammonium sesquicarbonate, sal-volatile, ammonii carbonas (U. S. P., Br.), $NH_4HCO_3 + NH_2NH_2CO_2$, is the commercial carbonate of ammonia, and was formerly prepared by the dry distillation of bones, horns, and other animal substances. It is at present prepared by heating a mixture of ammonium chloride or sulphate with calcium carbonate, and condensing the volatilized product. As seen by the formula, it is a mixture of the acid carbonate and the carbamate, though probably when fresh it consists of the pure neutral carbonate. So prepared, it sublimes as a white, transparent, hard mass, having an ammoniacal odor and an alkaline reaction. On exposure to the air, it gives off ammonia and carbon dioxide, and is therefore of uncertain composition. The carbonates of ammonia are very unstable.

Ammonium nitrate, ammonii nitras (U. S. P., Br.), NH_4-NO_3, is prepared by neutralizing nitric acid with ammonium hydroxide or carbonate. It crystallizes in flexible, six-sided prisms, without water; dissolves in 0.5 part water at 15° C. (59° F.), and fuses at 165° C. (329° F.). When heated to 210° C. (410° F.), it decomposes, with the formation of nitrous oxide, or laughing-gas, and water.

$$(NH_4)NO_3 = N_2O + 2H_2O.$$
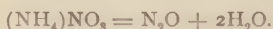
Ammonium sulphate, neutral ammonium sulphate, $(NH_4)_2$-SO_4, may be obtained by saturating the ammonia water from gasworks with sulphuric acid, separating the crystals and recrystallizing. It forms rhombic crystals, soluble in two parts of cold and one part of hot water. At 140° C. (284° F.) it fuses, and at higher temperatures it decomposes into ammonia, nitrogen, water, and ammonium sulphite.

Ammonium acetate, $(NH_4)C_2H_3O_2$, is formed when acetic acid is saturated with ammonia water, or ammonium carbonate. It is seldom seen except in solution in water. The aqueous solution is used in medicine as the **liquor ammonii acetatis,** or **spirit of mindererus,** which contains about seven per cent. of the salt.

Other salts in use are the **benzoate, phosphate,** and **valerianate,** all white, crystalline salts. The **benzoate,** $NH_4C_7H_5O_2$, the **phosphate,** $(NH_4)_2PO_4$, and the **valerianate,** $NH_4C_5H_9O_2$, are official.

Ammonium sulphide, $(NH_4)_2S$, is a white, crystalline solid, formed by mixing dry hydric sulphide and ammonia at a low tem-

perature, —18° C. (about 0° F.). It is usually prepared by dissolving sulphur in the sulphydrate. It dissolves sulphur and the sulphides of arsenic, tin, and antimony, and is used in analysis for this purpose.

Ammonium sulphydrate, NH_4SH, is prepared by saturating a solution of ammonium hydroxide with hydrogen sulphide (sulphuretted hydrogen). It is colorless at first, but becomes yellow on exposure, from decomposition. It is used in laboratories as a reagent. Acids decompose both these sulphides, setting free sulphur.

Action on the Economy.—In large quantities, or by prolonged use, ammonia and its salts are poisonous. Ammonia, if inhaled, acts as a severe irritant upon the air-passages, causing dyspnea, pain, suffocation, and even death. The treatment in cases of poisoning consists in neutralizing the alkali with dilute acids, or in using the vapor of acetic acid as an inhalation. Two drachms of a strong solution of ammonium hydroxide have proved fatal.

COPPER (Cuprum).

$$Cu = 63.6.$$

Occurrence.—This metal occurs in the free state in large masses, or crystallized in cubes and octahedra. It is found in the vicinity of Lake Superior, in China, Japan, Sweden, and in the Urals. Its most important ores are: **cuprite,** Cu_2O, **malachite,** and **azurite** (basic carbonates). **chalcocite,** Cu_2S, and **chalcopyrite,** or copper pyrites, $CuFeS_2$.

Preparation.—The mixed copper ores are first roasted in the air, by which process a portion of the copper, if a sulphide, is converted into oxide. This is then roasted with a silica flux and carbon. By this process the iron sulphide is converted into a silicate, and is drawn off with the slag. After several repetitions of this process the so-called **copper-stone** is obtained. This contains both the sulphide and the oxide. By repeated roasting and heating, the copper oxide reacts upon the sulphide, and metallic copper results. Some poor ores are first treated with sulphuric acid, and the resulting sulphate is then treated with scrap-iron, which precipitates the copper in the metallic state. Chemically pure copper is obtained by electrolysis, or by heating the pure oxide in a stream of hydrogen.

Properties.—Copper is a red metal by reflected light, while thin leaflets transmit a green light.

It is soft, ductile, and tenacious; a good conductor of heat and electricity; sp. gr., 8.914 to 8.952. In dry air it undergoes no

change, but in moist air it gradually becomes coated with a thin layer of green basic carbonate. When heated, it oxidizes to black cupric oxide, CuO. Hot sulphuric, nitric, and hydrochloric acids dissolve it, with the liberation of sulphur dioxide, nitrogen dioxide, and hydrogen, respectively. With organic acids it forms soluble salts in the presence of air and moisture; hence, acid fruits should not be kept in copper vessels.

Cuprous Compounds.—These are very unstable, absorb oxygen, and are converted into cupric compounds.

If the formulæ CuCl, CuI, Cu₂O, and Cu₂S are correct, copper in the cuprous compounds would appear, like silver, to be univalent. It has never been determined, however, whether these formulæ really express the true molecules. Copper compounds are not volatile, and we have no means of ascertaining the size of the molecule. As has already been stated, most chemists believe that in the cuprous compounds copper is bivalent, and that they contain the group $\begin{matrix} Cu' \\ | \\ Cu' \end{matrix}$, whose valence is always two.

Cuprous chloride, subchloride, or **protochloride,** Cu_2Cl_2, is produced, together with cupric chloride, by igniting metallic copper in chlorine gas, or by dissolving cuprous oxide in hydrochloric acid without contact of air, or by the action of many reducing agents upon solutions of cupric chloride. It is a heavy white powder, rapidly becoming green in the air, owing to the absorption of oxygen and the formation of cupric chloride, $Cu{<}^{Cl}_{Cl}$. It dissolves in concentrated hydrochloric acid, but not in water. With carbon monoxide it forms a crystallizable compound. Its hydrochloric acid solution is used in gas analysis to absorb this gas.

Cuprous iodide, Cu_2I_2, is precipitated, together with iodine, from soluble cupric salts by potassium iodide.

$$2CuSO_4 + 4KI = 2K_2SO_4 + Cu_2I_2 + I_2.$$

On dissolving out the iodine with ether, the iodide is left as a gray, insoluble powder.

Cuprous sulphide, subsulphide, or **protosulphide,** Cu_2S, occurs in the mineral **chalcocite,** as soft, fusible, gray crystals; also in many double sulphides, among which the most important is the double sulphide of copper and iron, or **copper pyrites.**

Cuprous oxide, suboxide, Cu_2O, occurs in nature as **cuprite.** It is obtained artificially by boiling an alkaline solution of grape-sugar and copper sulphate. It precipitates as a bright-red powder. (Fehling's and Trommer's tests.) The hydroxide, $Cu_2(OH)_2$, is precipi-

tated by the alkalies, from hydrochloric acid solutions of Cu_2Cl_2, as a yellow powder.

Cupric Compounds.—Cupric chloride, $CuCl_2$, is formed by dissolving cupric oxide or carbonate in hydrochloric acid. From aqueous solutions it crystallizes in bright-green, rhombic needles with $12H_2O$. It is readily soluble in water and alcohol. When heated, it parts with its water and forms anhydrous cupric chloride, which at a red heat gives off chlorine.

$$2CuCl_2 + heat = Cu_2Cl_2 + Cl_2.$$
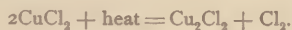
Cupric bromide resembles the chloride. The iodide is not known.

Cupric oxide, binoxide, black oxide, CuO, is prepared by heating copper turnings to redness in the air, or by calcining the nitrate. It forms a black, amorphous powder, readily reduced to the metallic state when heated with charcoal, hydrogen, or the alkaline metals. If heated in the presence of organic substances, it oxidizes them completely, and is thereby reduced to the metal. It is used in organic analysis for this purpose.

Cupric hydroxide, $Cu(OH)_2$, is formed as a voluminous bluish-white precipitate when sodium or potassium hydroxide is added to a solution of a copper salt. When heated, even under water, it becomes dehydrated and changed to black cupric oxide.

Copper oxide and hydroxide dissolve in ammonium hydroxide, forming a dark-blue solution. This solution is often used as a solvent for cellulose, from which acids precipitate it again.

Cupric sulphate, blue vitriol, blue stone, cupri sulphas (U. S. P., Br.), $CuSO_4.5H_2O$, is the only official salt of copper. It may be prepared, first, by roasting chalcocite; second, from the water of certain copper mines; third, by exposing copper, moistened with diluted sulphuric acid, to the air; fourth, by dissolving copper oxide in hot, concentrated sulphuric acid.

$$CuO + H_2SO_4 = CuSO_4 + H_2O.$$
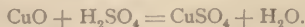
It forms large, blue, triclinic crystals, which dissolve in 2.6 parts of water at $15°$ C. ($59°$ F.), and in 0.55 part of water at $100°$ C. ($212°$ F.). It loses four molecules of water at $100°$ C. ($212°$ F.), while the fifth separates above $200°$ C. ($392°$ F.), leaving a white, amorphous powder, which readily takes up water, and in so doing resumes its blue color. Solutions of copper salts have a blue color, acid reaction, and metallic, styptic taste.

Ammonium hydroxide added to a solution of copper sulphate pre-

cipitates a bluish-white cupric hydroxide, which dissolves in an excess of the alkali, forming a deep-blue solution consisting of **ammonio-sulphate of copper**, or **cupric-tetrammonium sulphate**, $Cu(NH_3)_4SO_4.H_2O$. This solution is used as a test for arsenic. Alcohol precipitates from this solution long, right rhombic prisms of cupric-tetrammonium sulphate, which are very soluble in water.

Cupric sulphate also enters into the **alkaline cupric tartrate solution—Fehling's solution.**

Cupric Carbonates.—The neutral carbonate, $CuCO_3$, is not known. When alkaline carbonates are added to solutions of copper salts, the basic carbonate separates as a green precipitate, having the formula $CuCO_3.2Cu(OH)_2$. This salt occurs in nature, especially in Siberia, as **malachite**. Another basic salt, **tricupric carbonate**, or **sesquicarbonate** of copper, composes the beautiful blue mineral, **azurite.**

Copper arsenite, Scheele's green, is prepared by adding a solution of sodium or potassium arsenite to a solution of a copper salt. It is a green powder, composed of copper arsenite and copper hydroxide. It is insoluble in water, but soluble in ammonium hydroxide or the mineral acids. It is exceedingly poisonous, but is often used as a pigment to color wall-papers, toys, and even confectionery.

Schweinfurt green, mitis green, or **Paris green,** $Cu(C_2H_3O_2)_2.$ $3CuO.As_2$, is the commonest and most dangerous of the cuproarsenical pigments. It is prepared by adding a concentrated solution of cupric acetate to a boiling solution of arsenous acid. It is an insoluble, green, crystalline powder, decomposed by prolonged boiling in water, by aqueous solutions of the alkalies, and by the mineral acids. It is soluble in ammonium hydroxide.

Cupric acetate, $Cu(C_2H_3O_2)_2$, is formed by the decomposition of a solution of copper sulphate by lead acetate. It crystallizes in large, bluish-green, prismatic crystals, with one molecule of H_2O, which it loses at 140° C. (284° F.). The dry salt, when heated to 250° C. (482° F.), decomposes, with the liberation of glacial acetic acid.

Basic Acetates.—Verdigris, cupric subacetate, is a complex mixture of copper acetate and hydroxide. It is prepared by exposing to the air piles composed of alternate layers of grape-skins and copper plates, and after some time removing the bluish-green coating from the plates.*

Copper Pigments.—The most important are : **Brighton green,**

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* The term " verdigris " is now often popularly applied to the green carbonates, hydroxides, or salts of organic acids, which accumulate on the surface of copper.

a mixture of copper acetate and chalk ; **Brunswick green**, origi-
nally an impure chloride, but now generally a mixture of the carbonate
and chalk ; **mountain green**, or **mineral green**, a native green
carbonate of copper, sometimes containing orpiment ; **Neuwieder
green**, a mixture of mineral green or Schweinfurt green with
gypsum or barium sulphate ; **green verditer**, a mixture of the
basic carbonate, the oxide, and chalk.

Physiological Action of Copper.—Until recently toxicologists
were universally of the opinion that all the copper salts were poison-
ous. Of late, however, this has been considerably modified. Most
of the copper compounds have an irritant, local action if brought into
contact with the gastric or intestinal mucous membrane, causing
vomiting of greenish matter, cramps, etc. On the other hand, there
are numerous instances in which severe illness, characterized by
nervous and other constitutional symptoms, have followed the use of
food that has been in contact with imperfectly tinned copper vessels.
Some such cases have proven fatal. It has been conclusively shown,
however, that **pure** and non-irritating copper compounds may be
taken in considerable quantity without any bad results.

Copper sulphate is frequently used as an astringent in medicine,
and has been recommended in cholera and dysenteric troubles. This
salt may be taken in considerable doses, with only an emetic effect.
Cases of acute poisoning are not common, but some are recorded.
Chronic poisoning is occasionally seen in those who work in copper,
characterized by colicky pains, emaciation, impaired digestion, diar-
rhea, and often a catarrhal cough. In most cases there is a green line
on the margin of the gums. Copper is very likely to become con-
taminated with arsenic ; and it is possible that some of the cases of
reported copper poisoning ought to be attributed to arsenic. The
organic salts of copper seem to be more poisonous than the inorganic.
Canned peas, pickles, and other fruits are often contaminated with
copper, and the manufacturers have frequently been punished by fines ;
but there exists a difference of opinion as to the dangers of copper in
such goods. As long, however, as there is a chance for doubt, sani-
tary authorities should prohibit its use. The chemist must remember
that most articles of food contain traces of copper.

The treatment of cases of irritant copper poisoning should consist
in the exhibition of milk, white of egg, and other albuminous sub-
stances, with which the copper salt may form an inert compound.
Emesis should be induced if it has not taken place spontaneously.

SILVER (Argentum).

$$Ag = 108.$$

Occurrence.—This metal occurs in nature in combination with chlorine, bromine, iodine, sulphur, arsenic, copper, antimony, etc. The principal localities in which it is found are the western United States, Mexico, Hungary, and Saxony.

It is found native to some extent. The lead ore, **galena**, furnishes much silver.

Preparation.—For a description of the elaborate processes by which silver is extracted from its ores, the student is referred to works on metallurgy. As usually obtained by these processes the metal is not pure, but is contaminated to a greater or less extent by copper and other metals. To obtain it chemically pure, the ordinarily occurring silver is dissolved in nitric acid, and from this solution of the nitrates silver is precipitated as chloride by hydrochloric acid or common salt. The silver chloride thus obtained may be reduced by fusion with sodium carbonate, or by the action of zinc or iron in the presence of water and HCl.

$$2AgCl + Zn = ZnCl_2 + 2Ag.$$

Properties.—It is a brilliant white metal. Its sp. gr. is 10.47 to 10.54. It is tolerably malleable, soft, very ductile, and is the best-known conductor of heat and electricity. It does not oxidize in the air, but frequently tarnishes in ordinary atmospheres from the presence of minute quantities of hydrogen sulphide, which blacken it. It unites directly with the members of the **halogen group.** It dissolves in hot, strong sulphuric acid, to form the sulphate.

$$Ag_2 + H_2SO_4 = Ag_2SO_4 + H_2.$$

It is more easily attacked by nitric acid, which dissolves it with great readiness, even when largely diluted.

$$6Ag + 8HNO_3 = 6AgNO_3 + 4H_2O + N_2O_2.$$

In order to give it the necessary hardness for use in the arts, it is usually alloyed with copper. Coin-silver contains ten per cent. of copper in the United States, France, Germany, and Austria.

Silver chloride, AgCl, is formed whenever hydrochloric acid or a soluble chloride is added to aqueous solutions of silver salts, as a curdy, white precipitate.

$$AgNO_3 + HCl = AgCl + HNO_3.$$

It is insoluble in acids, but soluble in solutions of alkaline chlorides, hyposulphites, and cyanides, and freely so in ammonium hydroxide. It may be crystallized from ammoniacal solutions in large, regular octahedra.

Silver bromide, AgBr, precipitates from solutions of silver salts on the addition of hydrobromic acid or a soluble bromide.

$$AgNO_3 + HBr = AgBr + HNO_3.$$

With the exception of not being quite so soluble in ammonium hydroxide, it very closely resembles silver chloride.

Silver iodide, AgI, **argenti iodidum** (U. S. P.), differs from the chloride and bromide in its yellow color and insolubility in ammonia. Actinic rays of light change the color of silver chloride, bromide, and iodide, first to violet, then brown, and finally black. The bromides and iodides are more sensitive to light than the chloride.

Silver oxide, silver monoxide, silver protoxide, argenti oxidum (U. S. P., Br.), Ag_2O, is precipitated from solutions of soluble silver salts, by sodium or potassium hydroxide, as a dark-brown, faintly alkaline powder, slightly soluble in water.

$$2AgNO_3 + 2KOH = Ag_2O + 2KNO_3 + H_2O.$$
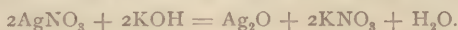
It has strong basic properties. It readily gives up its oxygen when heated. It should not be triturated with substances which are readily oxidizable, or combustible, as it is easily reduced. When the solution in ammonium hydroxide is evaporated, there separate black crystals of an explosive compound, $Ag_2O.2NH_3$, which, when dry, explode on the slightest disturbance.

Silver suboxide, Ag_4O, and **silver peroxide,** AgO or Ag_2O_2, are also known.

Silver nitrate, argenti nitras (U. S. P., Br.), $AgNO_3$, is prepared by dissolving pure silver in a somewhat diluted nitric acid, evaporating, recrystallizing, and washing with strong nitric acid. It separates in large, anhydrous plates, soluble at ordinary temperatures in one part of water or twenty-six parts of alcohol, and forms colorless solutions.

On exposure to light, in the presence of organic matter, its solutions turn black and deposit metallic silver. It has been proposed to use this reaction as a test for organic matters in potable waters. Chlorine and iodine decompose it, with the liberation of anhydrous nitric acid and the formation of a chloride or an iodide. When fused and cast into cylindrical molds, it forms the **argenti nitras fusus** (U. S. P.), **lapis infernalis,** or **lunar caustic** of pharmacy. **Argenti nitras**

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dilutus (U. S. P.), **argenti et potassii nitras** (Br.), (mitigated caustic), is an official preparation, made by melting together thirty parts of silver nitrate and sixty parts of potassium nitrate, and casting in suitable molds.

This salt is also used in photography, in the manufacture of hair-dyes, marking-ink, and in the silvering of glass.

Silver cyanide, argenti cyanidum (U. S. P.), AgCN, pre-cipitates from silver nitrate solutions as a white, curdy mass, on the addition of potassium or sodium cyanide. It is freely soluble in an excess of the reagent. It is also soluble in ammonium hydroxide and sodium thiosulphate, but is not affected by light. A solution of this compound in potassium cyanide is used as the plating bath in electro-plating with silver.

Silver Salts in Photography.—The property of undergoing reduction to the metallic state, by the action of light and organic matter, makes the silver salts useful in photography.

In taking a photograph a negative is first prepared, as follows: A plate of glass, previously well cleaned, is evenly covered by floating over it a solution of collodion (a solution of **pyroxylin** in ether and alcohol) containing a small quantity of iodide or bromide of potas-sium, and then dried. On dipping the plate into a solution of silver nitrate, it becomes coated with a layer of silver iodide or bromide. After exposure in the camera, it is taken to the dark room and " **developed** " by pouring upon it a solution of pyrogallic acid or ferrous sulphate, which reduces the silver salts to the metallic state on that portion of the plate that has been acted upon by light, and makes it opaque. In printing from this, a sheet of albuminized paper, pre-viously floated upon a solution of silver nitrate and then dried, is placed behind the negative and exposed to a strong light. The same action takes place upon the paper, the lights upon the negative be-coming dark upon the paper. The image is fixed by dissolving off the undecomposd silver with a solution of sodium hyposulphite.

GOLD (Aurum).

Au = 197.

Occurrence.—Native gold occurs widely distributed, though in small quantities. It is sometimes found in the form of beautiful crys-tals, belonging to the cubical system, but generally as veins in quartz. It is also found in the beds of various rivers, in the form of a granular dust. This may be separated by simple washing, the simplest device being the " pan," which is a round dish of sheet-iron, with sloping

sides, about twelve or fourteen inches in diameter. This pan is about half filled with the mud and sand to be washed, and is held in a stream of water and rotated in such a way that the lighter material is carried away and the gold left. When larger quantities are to be washed, the "cradle" is used. The gold-dust so obtained, or the gold-quartz which has been pulverized, is treated with mercury, which forms an amalgam with the gold. This amalgam is then placed in a retort and heated. The mercury distils over, leaving the gold behind.

Properties.—Gold is orange-yellow by reflected light and green by transmitted light, and is very ductile and exceedingly malleable. It fuses at 1200° C. (2192° F.), has a sp. gr. of 19.36, and is a good conductor of heat and electricity. It retains its luster even at high temperatures. It is not affected by any single acid or by alkaline hydroxides. A mixture of nitric and hydrochloric acids readily dissolves it, forming a solution of the chloride. It combines directly with the halogens and with phosphorus, antimony, arsenic, and mercury. In handling bromine, care should be taken that its vapor, or the bromine itself, does not come in contact with rings or other gold jewelry, lest they be attacked.

Uses.—Gold preparations are not extensively used in medicine. It is extensively employed, however, in the manufacture of jewelry, and for coinage. For either of these purposes it is too soft to be used alone, but is always alloyed with either copper or silver. In estimating the fineness of gold in jewelry, it is divided into twenty-four equal parts, called **carats.** The alloy is said to be of so many **carats** fineness when it contains that number of twenty-fourths of pure metal. Eighteen-carat gold is, then, $\frac{18}{24}$ gold and six carats base metal.

Aurous chloride, AuCl, is a pale yellow, insoluble powder, formed by heating auric chloride to 200° C. (392° F.).

Auri et sodii chloridum (U. S. P., Br.), $AuCl_3 + NaCl$, is used in medicine. It is a yellow, deliquescent solid, having a saline, metallic taste and an acid reaction. It is soluble in water and in alcohol. It is not a chemical compound, but a mixture of auric chloride, $AuCl_3$, and sodium chloride, NaCl, in equal parts by weight. It is decomposed by heat, and metallic gold separates.

Auric chloride, gold trichloride, $AuCl_3$, occurs in deliquescent prisms, soluble in water, alcohol, and ether. With phosphorus, or with reducing agents, it is readily decomposed, with the separation of gold. When in solution, it gives, with stannous chloride, a beautiful purple, flocculent precipitate,—**purple of Cassius,**—which is used to ornament glass and porcelain. Auric chloride is used in photography for "toning." The silver print is placed in the gold solution, when

metallic gold is deposited upon the silver picture, thus giving it a yellow tint or " tone."

Aurous oxide, Au_2O, is a dark violet powder, formed by the action of potassium hydroxide upon aurous chloride. Hydrochloric acid changes it into auric chloride and gold.

Auric oxide, Au_2O_3, is prepared by digesting magnesium oxide in a solution of auric chloride, decomposing the magnesium aurate with nitric acid, and drying the residue at 100° C. (212° F.). It is a dark brown powder, which decomposes easily, and unites readily with positive oxides to form **aurates,** having the general formula $RAuO_2$. It will thus be seen, from its behavior with oxygen, that gold is either monad or triad.

GROUP II. METALS OF THE ALKALINE EARTHS.

Beryllium, **Be** = 9.
Calcium, **Ca** = 40.
Strontium, **Sr** = 87.66.
Barium,   **Ba** = 137.43.

The metals of this group are called metals of the alkaline earths, because their oxides resemble, on the one hand, the oxides of the alkali metals, and, on the other, the real earths (alumina, etc.). Like the potassium group, their chemical energy increases gradually with their atomic weights. Their basic properties also become greater with their atomic weights. Thus, barium decomposes water more energetically and oxidizes more readily than strontium or calcium. Barium hydroxide is likewise the strongest base. It is quite soluble in water. It fuses without decomposition and absorbs carbon dioxide rapidly from the air. Calcium hydroxide possesses weaker basic properties, is difficultly soluble in water, and, when ignited, breaks up into water and calcium oxide. Strontium stands between barium and calcium. Thus, although these metals resemble the alkali metals, both in their free state and as hydroxides, they differ essentially from them in the insolubility of their carbonates and phosphates, and still more of their sulphates. Barium sulphate is insoluble in water and acids.

CALCIUM.

Ca = 40.

Occurrence.—This metal forms one of a class of elements most widely distributed in nature. Its carbonate (limestone, marble, and chalk), its sulphate (gypsum and alabaster), and its phosphate, fluoride, and silicate are common minerals.

Preparation.—Calcium may be obtained by electrolysis from the fused chloride, or by heating calcium iodide with sodium, or calcium chloride with sodium and zinc.

Properties.—It is a light yellow, lustrous, ductile metal. It fuses at a red heat, does not sensibly volatilize, and burns in the air with a brilliant reddish-yellow light. It does not undergo oxidation in dry air, but in moist air covers itself with a layer of hydroxide. Its sp. gr. is 1.577.

Calcium chloride, calcii chloridum (U. S. P., Br.), $CaCl_2$, is prepared by the action of hydrochloric acid upon marble. It crystallizes with six molecules of H_2O, in large, six-sided prisms, which are bitter, deliquescent, and very soluble in water. If heated, it melts in its water of crystallization, with some loss of water. At about 200° C. (392° F.) it becomes anhydrous. The fused calcium chloride is the official salt. It is a white mass, slightly translucent, having a sharp, saline taste, but no odor. The dry salt is a white, porous mass, which fuses at a red heat and solidifies to a crystalline mass, which rapidly absorbs water and is used as a drying agent for gases and liquids other than water. **Calcium iodide,** CaI_2, and the **bromide, calcii bromidum,** $CaBr_2$, are very similar to the chloride.

Chloride of lime, chlorinated lime, bleaching powder, calx chlorata (U. S. P.), **calx chlorinata** (Br.), is a mixture of calcium chloride. $CaCl_2$, and calcium hypochlorite. $Ca(ClO)_2$, with some CaO_2H_2. The hypochlorite is the active principle. It is prepared by passing chlorine over slaked lime.

From the analogous action of chlorine upon sodium or potassium hydroxide, we may express the reaction in the case of calcium hydroxide by the following equation:

$$2Ca(OH)_2 + 2Cl_2 = Ca(OCl)_2 + CaCl_2 + 2H_2O.$$
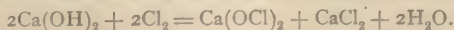
According to this equation, the completely chlorinated chloride of lime must contain 48.9 per cent. of chlorine, which is never the case, as a portion of the calcium hydroxide always remains unchanged. The exact constitution of chloride of lime is in doubt; but from more recent observations it is believed by some that the active constituent of chloride of lime is a basic calcium hypochlorite, $Ca{<}{OCl \atop OH}$, and the following reaction takes place when chlorine acts upon calcium hydroxide:

$$3Ca(OH)_2 + 2Cl_2 = 2CaO_2HCl + CaCl_2 + 2H_2O.$$
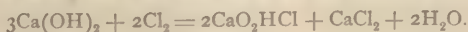
Calculating from this equation, completely saturated chloride of lime contains only thirty-nine per cent. chlorine, which is found to be actually the case.

Others regard chloride of lime as a chlorohypochlorite, having the graphic formula $CaCl - O - Cl$, and formed according to the following reaction: $Ca(OH)_2 + Cl_2 = CaOCl_2 + H_2O$. It is claimed that when this compound is dissolved in water it decomposes into CaO_2Cl_2 and $CaCl_2$. This idea of its composition seems to me improbable.

Chloride of lime is a grayish-white, porous powder, having a bitter, acrid taste and a chlorine-like odor. It is alkaline in reaction, soluble in cold and decomposed by boiling water. It slowly decomposes in the air, the carbon dioxide liberating hypochlorous oxide. This decomposition is hastened by sunlight and heat.

$$Ca(ClO)_2 + CaCl_2 + 2CO_2 = 2CaCO_3 + 2Cl_2.$$
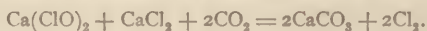
Diluted mineral acids decompose it very rapidly, with the liberation of chlorine.

$$Ca(ClO)_2 + CaCl_2 + 4HCl = 2CaCl_2 + 2H_2O + 2Cl_2.$$
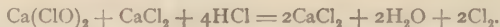
The efficiency of chloride of lime as a bleaching and disinfecting agent depends upon this production of free chlorine. The amount that will be set free by acids is called the **available chlorine**, which in good chloride of lime should be at least twenty-five per cent. The official **calx chlorata** should contain not less than thirty-five per cent.

Calcium oxide, lime, calx (U. S. P., Br.), CaO, is obtained pure by igniting the carbonate or nitrate. On a large scale it is prepared commercially by heating the natural carbonate (limestone or marble) in rude stone furnaces, called lime-kilns. It is a grayish-white, alkaline, and caustic amorphous solid. Sp. gr., 2.3. It does not fuse at any temperature at our command. When the oxyhydrogen flame is thrown upon it, it becomes incandescent and emits an extremely intense, white light (calcium or Drummond light). It combines energetically with water to form the hydroxide, the process being known as **slaking,** and is attended with the evolution of much heat.

$$CaO + H_2O = Ca(OH)_2.$$
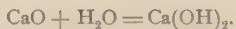
It is used for making building mortar. When lime is exposed to the air for some days, it absorbs moisture, becomes **air-slaked,** and crumbles to a powder.

Calcium hydroxide, slaked lime, calcii hydras (Br.), $Ca(OH)_2$, is a dry, white powder, odorless, and alkaline in reaction. It is slightly soluble in cold and less so in hot water. Exposed to the air, it absorbs carbon dioxide and forms the carbonate. Ordinary

mortar is a mixture of slaked lime, water, and quartz sand. The hardening of mortar depends upon three causes: (1) The evaporation of the water. (2) The absorption of carbon dioxide from the air and the formation of calcium carbonate:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$
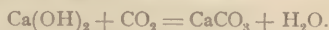
(3) The action of the basic hydroxide upon the silicic acid of the sand, producing calcium silicate.

$$Ca(OH)_2 + SiO_2 = CaSiO_3 + H_2O.$$

This last reaction takes place slowly; hence the hardness of old mortars. Hydraulic mortar, or **cement,** contains calcium oxide, aluminum silicate, and quartz powder; its hardening depends principally upon the formation of calcium and aluminum silicates.

Lime-water, liquor calcis (U. S. P., Br.), is a clear, saturated solution of calcium hydroxide in water.

The percentage of $Ca(OH)_2$ varies with the temperature. It contains about 0.17 per cent. at the ordinary temperature, but when the temperature rises the solution becomes weaker.

Cane-sugar increases the solubility of calcium hydroxide, with which it forms a saccharate. The British **liquor calcis saccharatus** is a solution of calcium hydroxide in a strong solution of cane-sugar.

Syrupus calcis (U. S. P.) is an analogous preparation.

When lime-water contains an excess of the hydroxide, rendering it turbid, it is called milk of lime.

Calcium carbide, C_2Ca, is prepared by heating in an electrical furnace an intimate mixture of coal-tar and lime. The mass fuses and can be poured out of the crucible, and on cooling is found to be composed of carbon mixed with lustrous, dark-brown or black masses of calcium carbide. These masses are hard and brittle, giving a crystalline fracture. On exposure to moist air, it decomposes and loses its luster. The most interesting property of C_2Ca is its decomposition when brought in contact with water.

$$\underset{\substack{\text{Calcium} \\ \text{Carbide.}}}{C_2Ca} + \underset{\text{Water.}}{2H_2O} = \underset{\text{Acetylene.}}{C_2H_2} + \underset{\substack{\text{Calcium} \\ \text{Hydroxide.}}}{CaO_2H_2}.$$

The acetylene produced is pure, and burns with a smoky flame. When diluted with from six to ten volumes of air, it gives a flame of great brilliancy and intensity. This compound is interesting because it can be cheaply made, and serves to bridge over the gap between inorganic and organic substances, and allows us to prepare, on a

manufacturing scale, an organic compound from the elements. It is now made on a large scale, and is an article of commerce.

Calcium sulphate, $CaSO_4$, occurs very abundantly as **gypsum,** in right rhombic prisms, combined with two molecules of water. The anhydrous salt forms the mineral **anhydrite.** It is very sparingly soluble in water. At ordinary temperatures 1 part dissolves in 400 parts H_2O. Ground gypsum is used in the arts under the name of **terra alba.** When heated to about 120° C. (248° F.) it parts with its water, becoming converted into an opaque, white mass, which, when ground, is called **plaster-of-Paris.** It is sometimes used as a fertilizer.

Calcii sulphas exsiccatus (U. S. P.), dried gypsum, contains about ninety-five per cent. of $CaSO_4$ and about five per cent. of water. It is prepared by heating pure native gypsum, $CaSO_4.2H_2O$, until about three-fourths of the water is expelled.

When mixed with water, this powder takes up two molecules and hardens into a stone-like solid. Upon this property depends the usefulness of plaster for making molds, figures, and immovable surgical dressings.

Calcium Phosphates.—Tricalcic, neutral, or **bone phosphate, calcii phosphas præcipitatus** (U. S. P.), **calcis phosphas** (Br.), $Ca_3(PO_4)_2$, is found in rocks, and especially in the mineral **apatite,**

$$3Ca_3(PO_4)_2CaF_2,$$
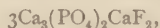
and in soils, in guano, in the ash of plants, and in every tissue and fluid of animal bodies.

It may be prepared pure by dissolving bone-ash in hydrochloric acid, filtering, and precipitating with ammonium hydroxide:

$$Ca_3(PO_4)_2 + 4HCl = CaH_4(PO_4)_2 + 2CaCl_2.$$
$$CaH_4(PO_4)_2 + 2CaCl_2 + 4NH_4OH = Ca_3(PO_4)_2 + 4NH_4Cl + 4H_2O.$$
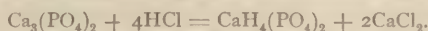
Also by double decomposition between calcium chloride and an alkaline phosphate. It is a gelatinous mass when first precipitated, but, after drying, a white, amorphous powder. It is insoluble in water, but readily soluble in dilute acids, even acetic ; also in water charged with carbon dioxide. An impure tricalcium phosphate, prepared by burning bones, is known as **bone-ash.**

Dicalcium phosphate, $Ca_2H_2(PO_4)_2$, separates as an amorphous, insoluble precipitate, when disodium phosphate is added to a strong solution of calcium chloride slightly acidified with acetic acid.

Monocalcium phosphate, acid calcium phosphate, superphosphate of lime, $CaH_4(PO_4)_2$, is found in brain-tissue and in acid animal fluids. It is produced by the action of sulphuric or

hydrochloric acid upon the first two phosphates, and is manufactured as a fertilizer, mixed with calcium sulphate, by decomposing bones with sulphuric acid.

$$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4.$$
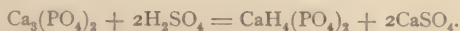
At a temperature of 200° C. (392° F.) it splits up into calcium pyrophosphate, metaphosphoric acid, and water.

$$2CaH_4(PO_4)_2 = Ca_2P_2O_7 + 2HPO_3 + 3H_2O.$$
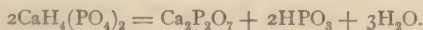
When this mixture is ignited with charcoal, the metaphosphate is formed, and reduced to phosphorus and $Ca_3(PO_4)_2$. (See p. 182.)

Calcium carbonate, calcii carbonas (U. S. P., Br.), $CaCO_3$, is of exceedingly wide distribution in nature. It exists sometimes in enormous deposits, as limestone, marble, chalk, Iceland spar, and as the mineral basis of the corals, shells of the crustacea, mollusks, etc. Chalk is a comparatively pure, amorphous, calcium carbonate, made up of microscopic shells.

Calcium carbonate is nearly insoluble in pure water, but dissolves readily in water containing carbon dioxide. Hence, we find it dissolved in nearly all natural waters, as a bicarbonate, $CaH_2(CO_3)_2$, giving rise to temporary hardness. Boiling, agitation, or free exposure to the air may decompose this salt and deposit the ordinary calcium carbonate. Upon this depends the formation of stalactites, boiler incrustations, and similar deposits.

Calcii carbonas præcipitatus (U. S. P., Br.) is made by mixing solutions of calcium chloride and sodium carbonate. Double decomposition takes place, and $CaCO_3$ is precipitated.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

The white precipitate of calcium carbonate is filtered off, washed with water, and dried. **Prepared chalk, creta præparata** (U. S. P., Br.), is a native chalk, purified by **elutriation**, which consists in grinding the chalk in water, allowing the mixture to partially subside, decanting the upper portion, allowing it to settle, and collecting and drying the fine powder.

Calcium oxalate, CaC_2O_4, is found in the juice of some plants and in the urine. It may be obtained, as a fine, white, crystalline powder, by adding any soluble oxalate to a soluble calcium salt dissolved in a neutral or alkaline solution.

$$(NH_4)_2C_2O_4 + CaCl_2 = 2NH_4Cl + CaC_2O_4.$$
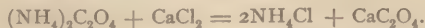
It is insoluble in water and acetic acid, but soluble in the mineral acids. In many diseased conditions which produce deficient oxida-

23

tion or excessive production of acids (lung disease and acid dyspepsia), it occurs in the urine in considerable quantities, and gives rise to **oxaluria,** or the oxalic acid diathesis. This salt frequently forms calculi, which present irregular projections and have received the name of **mulberry calculi.** Excessive saccharine diet, or excessive consumption of certain vegetables, as tomatoes, rhubarb, etc., increases the production and elimination of calcium oxalate.

Calcii hypophosphis (U. S. P., Br.), $Ca(PH_2O_2)_2$, is made by boiling together calcium hydroxide and phosphorus until combination is complete, and phosphoretted hydrogen, PH_3, ceases to be evolved.

$$3Ca(OH)_2 + 2P_4 + 6H_2O = 3Ca(PH_2O_2)_2 + 2PH_3.$$
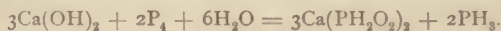
The solution is then filtered, evaporated, and the salt granulated. It is generally obtained as a white, granular powder, having no odor, but a nauseous, bitter taste.

Crude calcium sulphide, calx sulphurata (U. S. P., Br.), is made by mixing together dried calcium sulphate and powdered charcoal, and heating to bright redness in a loosely covered crucible until the black color of the mixture has disappeared. It is a mixture containing about sixty per cent. of CaS, with $CaSO_4$ and carbon in varying proportions. It has a pale-gray color and a slight odor of H_2S.

Physiological Effects and Uses.—The calcium salts play an important part in the animal economy. The phosphates are found in every tissue and fluid of the body, but most abundantly in the bones and teeth ; the former containing from fifty-five to fifty-nine per cent., and the latter, including the carbonate, seventy-two per cent. As the salts of lime are insoluble in alkaline fluids, various theories have been put forward to explain their state in the blood and other alkaline fluids. It seems certain that the calcium of blood-serum does not exist as phosphate, but as some soluble salt or albumin compound, soluble in alkaline fluids. The calcium phosphate of the urine remains in solution as long as that fluid is acid, but separates as an amorphous or crystalline sediment as soon as it undergoes alkaline fermentation. Alkaline urine is always turbid from the precipitation of the phosphate of Mg or Ca. When taken internally, the calcium salts produce effects similar to those of sodium and potassium, but milder. They have a mild astringent effect.

STRONTIUM.

$Sr = 87.6.$

Strontium is rather sparingly found in nature. The principal minerals are **strontianite**, $SrCO_3$, and **celestite**, $SrSO_4$. It is a brass-yellow, lustrous metal, which resembles calcium in its properties, as also do its compounds. This element exhibits most of the properties of calcium and barium. Strontium may be made by decomposing the chloride by electricity. Its compounds impart a red tinge to the flame, and for this reason the nitrate is used as a constituent of red fires. The solubility of its sulphate stands between that of calcium and barium. It has been used in medicine as an alterative. Its salts are poisonous only in large quantities.

Strontium Chloride.—$SrCl6_2H_2O$. This salt may be prepared by treating HCl with an excess of strontianite, and digesting the mixture for some time to allow the iron, aluminum, etc., to separate from the solution, which may then be drawn off and evaporated. On cooling, this concentrated solution deposits acicular crystals having a bitterish taste. They are soluble in 1.8 parts of water, are soluble in alcohol, and deliquesce in the air.

Strontium Bromide, Strontii Bromidum (U. S. P.).— $SrBr_2.6H_2O$. This salt may be prepared by saturating hydrobromic acid with strontium carbonate.

$$2HBr + SrCO_3 = SrBr_2 + CO_2 + H_2O.$$
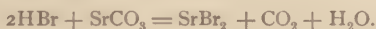
The clear solution is concentrated by evaporation and allowed to crystallize.

Strontium bromide occurs as deliquescent, colorless, odorless, transparent, hexagonal crystals, having a bitter, saline taste. It is soluble in 1.05 parts of water at 15° C. (59° F.). It is soluble in alcohol, but insoluble in ether. The crystals melt when heated, and lose all their water. This salt, as well as all the salts of strontium, imparts an intense red color to the non-luminous flame. It is used in medicine in doses of 1 gm. to 20 gm. per day.

Strontium Iodide, Strontii Iodidum (U. S. P.).—SrI_26H_2O. This salt is prepared by saturating hydriodic acid with strontium carbonate.

$$2HI + SrCO_3 = SrI_2 + CO_2 + H_2O.$$
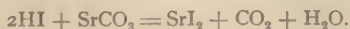
The solution is then evaporated and allowed to crystallize.

Strontium iodide occurs as colorless, odorless, transparent, hexagonal plates having a bitterish, saline taste. They deliquesce and turn

yellow on exposure to the air. The crystals are soluble in 0.6 part of cold water, are soluble in alcohol, and slightly so in ether. When heated they melt, and gradually lose their water. At a red heat they decompose, giving off iodine and leaving a residue of strontium oxide. This salt is used in medicine.

Strontium monoxide, SrO, **strontium dioxide,** SrO_2, and **strontium hydroxide,** SrO_2H_2, are known.

Strontium nitrate, $Sr(NO_3)_2$, prepared by dissolving the carbonate in nitric acid, has been recommended in articular rheumatism. It occurs as colorless crystals, soluble in five parts of water and permanent in the air.

Strontium phosphate, $Sr_3(PO_4)_2$, a white, tasteless powder, sparingly soluble in water ; **strontium acetate,** $Sr(C_2H_3O_2)_2$, **strontium carbonate,** $SrCO_3$, and **strontium sulphate,** $SrSO_4$, have been somewhat used as medicines.

Strontium Lactate, Strontii Lactas (U. S. P.).—$Sr(C_3H_5-O_3)_2.3H_2O$. This salt may be prepared by saturating a solution of lactic acid with $SrCO_3$. It is a white, granular, odorless powder, having a slightly bitter, saline taste.

It is permanent in the air, and soluble in four parts of water at 15° C. (59° F.), and soluble in alcohol. It loses its water at 110° C. (230° F.). It has been used in renal diseases associated with albuminuria, and as a teniafuge.

It is given in fifteen- to forty-grain doses.

BARIUM.

$Ba = 137.2.$

Barium is found in nature in the form of **barite,** $BaSO_4$, and also as **witherite,** $BaCO_3$.

The element itself is not of interest to the medical student.

Barium chloride, $BaCl_2.H_2O$, is prepared by the action of hydrochloric acid upon the native carbonate, using an excess of the latter, and allowing the mixture to stand a few days to allow the iron and other metals to precipitate. It is used as a reagent for soluble sulphates, giving a white precipitate, insoluble in acids or water.

It has been used in medicine as an alterative and anthelmintic.

Barium oxide, baryta, BaO, is obtained by calcining the nitrate. It is a grayish-white, caustic powder, fusible in the oxy-hydrogen flame. It unites with water, with the evolution of much heat, to form the hydroxide, BaH_2O_2. This, dissolved in water, forms baryta water.

Barium peroxide, barii dioxidum (U. S. P.), BaO_2, is a white powder, decomposed by dilute acids, with the production of hydrogen peroxide. It is the only official compound of barium. It is made by heating the oxide to a red heat in air or in oxygen. If the heat is raised too high, the oxygen, which was at first absorbed, is again given off.

$$2BaO + O_2 = 2BaO_2.$$
$$2BaO_2 = 2BaO + O_2.$$
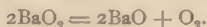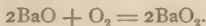
This power of absorbing oxygen from the air, and giving it off again at a higher temperature, has been used in manufacturing oxygen.

It is used in the manufacture of **hydrogen dioxide.**

Barium nitrate, $Ba(NO_3)_2$, forms anhydrous, octahedral crystals of the regular system, soluble in water, and used as a constituent of pale-green theater fires.

Barium sulphate, $BaSO_4$, **heavy spar** or **barite,** occurs in nature, both amorphous and in rhombic prisms. Sp. gr., 4.6. It is obtained as a white, amorphous powder, insoluble in acids and water, by the action of sulphuric acid upon other barium salts. It is used as an adulterant of white paint, Paris green, and a variety of other commercial products.

Barium carbonate, $BaCO_3$, occurs native, as **witherite.** It precipitates from solutions of barium salts, as a white, amorphous powder, when they are treated with soluble carbonates.

Physiological Effect of Barium Salts.—All the soluble compounds of barium, as well as those that are converted into soluble compounds in the stomach, are poisonous. Whenever a poisonous dose has been taken, the patient should take some soluble sulphate (as Epsom or Glauber's salt), followed by an emetic. The symptoms of poisoning are: pain in stomach, prostration, dilated pupils; loss of voice, sight, or hearing; excessive micturition, and other very prominent nervous symptoms. Postmortem, inflammation and, in most cases, great friability of the stomach, and, invariably, inflammation of the rectum are found.

GROUP III.   METALS OF THE MAGNESIUM GROUP.

Magnesium,	**Mg** =	**24.**
Zinc,	**Zn** =	**65.3.**
Cadmium,	**Cd** = **112.**	
Mercury,	**Hg** = **200.**	

MAGNESIUM.

$Mg = 24.$

Magnesium was formerly classed with the metals of the alkaline earths, but its sulphate is soluble and its chloride volatile, which, together with its properties in the free state, show it to be more closely related to zinc.

Occurrence.—It is found abundantly in nature.   Some of the most common minerals containing it are **magnesite,** $Mg.CO_3$; **kieserite,** $Mg.SO_4.H_2O$; **carnallite,** $KCl.MgCl_2.6H_2O$; and **dolomite.**

Dolomite, an amorphous mixture of calcium and magnesium carbonates, forms the so-called **magnesian limestone.   Asbestos, serpentine, meerschaum, talc** or **soapstone,** and **hornblende** are native silicates.   Nearly all natural waters contain traces of the soluble salts of magnesium, which impart hardness to them.

Preparation.—It may be obtained either by electrolysis of the chloride or by heating the same compound with sodium.

It was formerly prepared by fusing the double chloride of sodium and magnesium with metallic sodium.

$$MgCl_2.NaCl + Na_2 = 3NaCl + Mg.$$
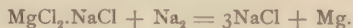
It is now generally prepared by the electrolysis of the fused chloride or the native carnallite.

The electrolysis is conducted in a steel vessel, which is made the negative pole, and the positive pole is made of gas-retort carbon. The current is supplied by a powerful dynamo, and a current of hydrogen is led into the chamber during the reduction to prevent oxidation of the metal.   It is purified by distillation in an atmosphere of hydrogen.

Properties.—Magnesium is a brilliant white, very tenacious, and ductile metal, of a sp. gr. of 1.75.   It fuses at a dull red heat, and distils at a bright red heat.   It oxidizes but slightly in the air at

ordinary temperatures, but, when heated, it burns with an intensely brilliant bluish-white light, owing to the incandescence of the magnesium oxide formed in the burning. The flame of burning magnesium is rich in chemically active or actinic rays ; hence it is much employed for photographing in dark caves and subterranean chambers. It combines directly with chlorine, sulphur, phosphorus, arsenic, and nitrogen, but not with argon. It is soluble in dilute acids, but not in alkalies. It is slowly oxidized by boiling water.

Magnesium chloride, $MgCl_2$, exists in small quantities in many mineral springs and in sea-water, to which it imparts a bitter taste. It may be obtained by dissolving the carbonate or oxide in hydrochloric acid. It forms deliquescent crystals, isomorphous with calcium chloride, containing six molecules of H_2O. The anhydrous chloride is one of the most deliquescent substances known.

Magnesium oxide, calcined magnesia, magnesia (U. S. P., Br.), MgO, is formed by the combustion of the metal, or by the ignition of the carbonate, hydroxide, or nitrate. It is a very light, white powder, without odor or taste, and has a feeble alkaline reaction. It is soluble in dilute acids.

A compact variety, prepared by heating the nitrate or chloride to bright redness, and no higher, exhibits remarkable hydraulic properties. If moistened with water to a paste, it quickly hardens to a compact white solid, of great hardness and durability. If it be mixed with an equal part of marble dust or chalk, and moistened, it may be molded into any desired shape, and on being placed in water it " sets " into an extremely hard mass. It has been used as a filling for decayed teeth.

Magnesia ponderosa (U. S. P., Br.), or heavy magnesia, does not differ in chemical composition from the light variety, but it differs merely in its physical condition.

Magnesium hydroxide, hydrated magnesia, $Mg(HO)_2$, is formed from any soluble magnesium salt by precipitating with sodium or potassium hydroxide. It is almost insoluble in water and alkalies, but soluble in ammonium salts, with the formation of double salts. A mixture holding it in suspension in water, known as **milk of magnesia,** is used in medicine as a laxative and as an antidote for acid poisons.

Magnesium sulphate, Epsom salt, magnesii sulphas (U. S. P., Br.), $(MgSO_4).7H_2O$, is found in solution in sea-waters and in many mineral springs, especially those belonging to the class of **bitter waters.**

It is prepared by the action of sulphuric acid upon magnesium carbonate. At ordinary temperatures it crystallizes with $7H_2O$, in four-sided rhombic prisms, which are very readily soluble in water. When heated, it fuses and parts with its water of crystallization up to 132° C.

(269.6° F.), when it has lost all but one molecule ; this it finally parts with when heated to 200° C. (392° F.). **One** molecule of water, therefore, is more closely combined than the rest. That is known as the **water of constitution,** to distinguish it from the **water of crystallization.**

Magnesium Phosphates.—These resemble the calcium phosphates, which they generally accompany in the animal body, though usually existing in smaller quantities. Magnesium also forms double phosphates, one of which, the **ammonio-magnesium phosphate,** or **triple phosphate,** $MgNH_4PO_4.6H_2O$, is precipitated when an excess of an alkaline phosphate and of ammonia is added to a solution containing magnesium. When the urine becomes ammoniacal from the decomposition of urea, this salt is precipitated, as urine always contains alkaline phosphates and magnesium salts. Being practically insoluble, especially in the presence of excess of ammonium hydroxide, it is usually deposited from the urine as a sediment, in the shape of modified right rhombic prisms, which, under the microscope, resemble the shape of a coffin-lid. This sometimes takes place in the bladder, and if some body is present that will act as a nucleus, a so-called **fusible calculus** may form.

Magnesium carbonate, neutral carbonate, $MgCO_3$, occurs in nature as **magnesite,** and, combined with calcium carbonate, in **dolomite.** On adding an alkaline carbonate to an aqueous solution of a magnesium salt, magnesium carbonate is not produced, as most other carbonates would be under similar circumstances, but some carbon dioxide escapes, and a white precipitate falls, which is a mixture of magnesium carbonate and hydroxide, or **magnesia alba.**

Tetramagnesium carbonate, magnesia alba, magnesii carbonas (U. S. P., Br.), $4MgCO_3.MgH_2O_2 + 5H_2O$, occurs in commerce in light white cubes, composed of an amorphous or partly crystalline powder. It is prepared by precipitating a solution of magnesium sulphate with one of sodium carbonate. A hot concentrated solution should be used, and the liquid boiled after precipitation. This compound varies in constitution according to the length of time that the boiling has continued and the presence or absence of excess of sodium carbonate. It is very slightly soluble in water, but quite soluble in solutions of ammonium chloride.

Magnesii citras effervescens (U. S. P.) is a granular salt consisting of citrate of magnesium with an excess of citric acid and some sodium bicarbonate. When dissolved in water it effervesces copiously, carbon dioxide being evolved. It has a mildly acidulous and refreshing taste. **Liquor magnesii citratis** (Br.) is the ordinary solution of citrate of magnesia used as a laxative.

ZINC.

$$Zn = 65.1.$$

Occurrence.—The native compounds of the heavy metals are termed **ores.** The most common zinc ores are **Smithsonite,** $ZnCO_3$, **calamine (silicate),** and **sphalerite** or **blende,** ZnS. These, like most ores, have a high specific gravity, and are usually found in veins in the older crystalline rocks.

Preparation.—To obtain the metal, one of its ores, usually the carbonate or sulphide, is converted into an oxide by roasting at a high temperature. This oxide is then mixed with carbon and ignited in cylindrical earthenware retorts, to reduce the oxide:

$$ZnO + C = Zn + CO.$$
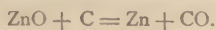
The free zinc is then distilled off and condensed in iron receivers, which are placed like caps over the openings of the retorts. The metal so obtained forms the **spelter** of commerce, and contains various impurities, such as iron, lead, arsenic, sulphur, and cadmium.

Zinc is purified by subjecting it to a second distillation. This is generally conducted in a covered vertical retort, which is provided with a tube, which passes through its bottom. The upper end of this tube reaches nearly to the top of the retort, and its lower extremity is just above a vessel of water. When the zinc is heated in this retort, it volatilizes and passes down the tube, and is condensed in the water. This method is known as "distillation per decentum."

Properties.—It is a bluish-white metal, roughly crystalline or granular; its sp. gr. is 6.862, if cast; 7.215, if rolled. It is brittle at ordinary temperatures, and can be pulverized; at 100° C. (212° F.) to 150° C. (302° F.) it is malleable and ductile, and may be rolled into thin sheets. At 200° C. (392° F.) it again becomes brittle. It fuses at 412° C. (773° F.) and distils at 1040° C. (1904° F.). In moist air it becomes coated with a thin layer of basic carbonate. When heated in the air, it burns with a very intense bluish-white light, with the formation of the oxide. It dissolves readily in dilute acids, with the evolution of hydrogen. Concentrated sulphuric acid does not dissolve zinc. It is soluble in sodium, potassium, and ammonium hydroxides. On account of the slight action of the air upon it, zinc meets with extensive application in architecture and for galvanizing or coating iron. **Zincum** is official in the U. S. P. in the form of thin sheets, or granular pieces, or molded into pencils, or in powder form. Granulated zinc is made by melting the metal and pouring it into water.

Zinc chloride, butter of zinc, zinci chloridum (U. S. P., Br.), $ZnCl_2$, is obtained by heating zinc in a stream of chlorine, by dissolving zinc in hydrochloric acid, and by the distillation of zinc sulphate with calcium chloride. It forms a soft, white mass, which is very deliquescent, is fusible and volatile. It is extremely soluble in water and freely so in alcohol. The solution has a burning, metallic taste, destroying animal and vegetable tissues, and possesses strong dehydrating properties. It forms a series of double salts. The double chloride of zinc and ammonium is sometimes used in soldering, to cleanse the surface of metals to be soldered.

Zinci bromidum (U. S. P.), $ZnBr_2$, may be made by dissolving zinc in hydrobromic acid, or by the direct combination of zinc and bromine.

$$2Zn + 4HBr = 2ZnBr_2 + 2H_2.$$
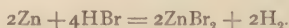
It is a white, granular powder, having no odor, but a sharp, metallic taste, very soluble in water and in alcohol, and very deliquescent.

Zinci iodidum (U. S. P.), ZnI_2, may be made by digesting small fragments of zinc in water containing some iodine, or by dissolving zinc carbonate or oxide in hydriodic acid.

$$ZnO + 2HI = ZnI_2 + H_2O.$$
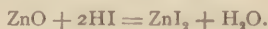
The solution is filtered through powdered glass and evaporated. It is a deliquescent, granular, white, odorless powder. It is soluble in water and in alcohol.

Zinci phosphidum (U. S. P.), Zn_3P_2, is made by passing the vapor of phosphorus over fused zinc in a current of dry hydrogen gas. It is a dark, gray-colored, gritty powder, or fragments. It has a metallic luster and a faint odor of phosphorus hydride. It is insoluble in water or alcohol. It dissolves in HCl, with evolution of phosphorus hydride.

Zinc oxide, zinci oxidum (U. S. P., Br.), ZnO, may be prepared by igniting the precipitated basic carbonate, or by burning the metal in a current of air. When obtained in the former way, it forms a soft, white, tasteless, and odorless powder. When produced by burning the metal, it occurs as a white, voluminous, flocculent mass, formerly called **flores zinci** or **lana philosophica**. It neither fuses, volatilizes, nor decomposes by heat, and is insoluble in neutral solvents. It is used in the arts as a white pigment, and is not darkened by hydrogen sulphide, as is white lead.

Zinc hydroxide, $Zn(OH)_2$, is formed as a white, amorphous powder, by precipitating an aqueous solution of a zinc salt by alkaline hydroxides. It is soluble in an excess of the alkaline hydroxides

and in solutions of ammonium salts. When heated, it decomposes into zinc oxide and water.

Zinc sulphate, white vitriol, zinci sulphas (U. S. P., Br.), $ZnSO_4.7H_2O$, is formed by dissolving zinc, or its oxide, sulphide, or carbonate, in sulphuric acid.

$$Zn_2 + 2H_2SO_4 = 2ZnSO_4 + 2H_2.$$
$$ZnO + H_2SO_4 = ZnSO_4 + H_2O.$$
$$ZnCO_3 + H_2SO_4 = ZnSO_4 + CO_2 + H_2O.$$
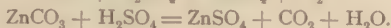
At temperatures below 30° C. (86° F.) it crystallizes with 7 Aq.; at 30° C. (86° F.), with 6 Aq.; between 40° C. (104° F.) and 50° C. (122° F.), with 5 Aq. The most common salt is that with 7 Aq., which occurs in rhombic crystals resembling magnesium sulphate, and is freely soluble in water. It is used in medicine as an emetic and astringent.

Zinci acetas (U. S. P., Br.), $Zn(C_2H_3O_2)_2.2H_2O$, is made by dissolving the carbonate or oxide of zinc in diluted acetic acid, evaporating, and crystallizing.

$$ZnO + 2HC_2H_3O_2 = Zn(C_2H_3O_2)_2 + H_2O.$$
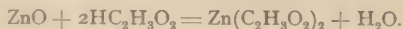
It occurs as soft, white tablets or scales, having a pearly luster, a faint odor of acetic acid, and a sharp, metallic taste. It is soluble in 2.7 parts of water at 15° C. (59° F.), in 1.5 parts of boiling water, and in 36 parts of alcohol.

Zinc valerianate, zinci valerianas (U. S. P., Br.), $Zn(C_5H_9O_2)_2.2H_2O$, occurs as white, pearly scales, having a strong odor of valerianic acid and a peculiar, sweet, styptic, metallic taste. Exposed to the air, it is decomposed, giving off valerianic acid. It is made by mixing hot solutions of sodium valerianate and zinc sulphate, and allowing the zinc valerianate to crystallize out.

Zinc Carbonate, Zinci Carbonas Præcipitatus (U. S. P., Br.). —This salt is made by mixing a boiling solution of sodium carbonate with a boiling solution of zinc sulphate. Mutual decomposition takes place, and a basic zinc carbonate is precipitated.

$$5ZnSO_4 + 5Na_2CO_3 + 3H_2O = (ZnCO_3)_2 . (Zn(OH)_2)_3 + 5Na_2SO_4 + 3CO_2.$$
Precipitated Zinc Carbonate.
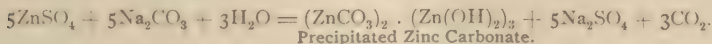
The precipitate is washed with hot water and dried.

It is a white, odorless and tasteless impalpable powder, insoluble in water or alcohol, and of variable chemical composition. The composition of the precipitate varies according to the temperature used.

Toxicology.—The compounds of zinc that are soluble in the digestive fluids are all irritant poisons. Solutions of the chloride (used by tinsmiths, in embalming, and as a disinfectant in Burnett's fluid) are also very corrosive. The antidotes are alkaline carbonates, soap, albumin, and mucilage. Solutions containing sodium chloride or organic acids act as solvents of metallic zinc; consequently, symptoms of poisoning, more or less marked, are apt to follow the eating of acid fruits that have been kept in vessels of galvanized iron. On this account, specimens intended for analysis, in case of supposed poisoning, should never be placed in jars closed by zinc caps.

Tests.—With **alkaline hydroxides** and **carbonates,** solutions of zinc give a white precipitate, soluble in an excess of the reagent; with **ammonium sulphydrate** or **sulphydric acid,** in neutral or alkaline solutions, a white sulphide; with **potassium ferrocyanide,** a yellowish-white precipitate, insoluble in diluted hydrochloric acid.

CADMIUM.

$Cd = 112.$

Occurrence, Preparation, Properties, etc.—It is a comparatively rare metal, often accompanying zinc in its ores. Being more volatile than its associate, it remains behind in the process of distilling zinc from its ores. It is a soft, white, tenacious metal, of sp. gr. 8.6. It alters but little in the air at ordinary temperatures. When heated, it burns, with the formation of the oxides, as a brown smoke. It dissolves with difficulty in sulphuric and hydrochloric acids, but readily in nitric acid.

Cadmium Compounds.—These are not very numerous or important. As the element is bivalent, they all have the general formula CdR_2. The principal ones are: cadmium hydroxide, $Cd(OH)_2$; cadmium oxide, CdO; cadmium chloride, $CdCl_2$; cadmium iodide, CdI_2; cadmium sulphate, $CdSO_4$; and cadmium sulphide, CdS. The latter is found native in the mineral **greenockite.**

Cadmium iodide and bromide are used in photography. Cadmium iodide, dissolved in an excess of potassium iodide solution, is used as a general reagent for alkaloids. The metal enters into the composition of several alloys which are used for filling teeth, such alloys having a low fusing point.

MERCURY (Hydrargyrum.)

(QUICKSILVER.)

$Hg = 200.$

Occurrence.—Mercury occurs in nature principally as **cinnabar,** HgS, or, rarely, in the form of small particles of metal scattered through rocks. It is found in Spain, Peru, China, Japan, California, and Mexico.

Preparation.—The native sulphide, or cinnabar, is roasted in reverberatory furnaces, thus burning out the sulphur and distilling off the mercury. Or, it is sometimes simply heated in a retort with iron, which combines with the sulphur and sets free the mercury, which distils over. Commercial mercury usually contains small quantities of other metals, owing to its great tendency to form alloys with them, called amalgams. To remove these it is redistilled, or treated with very dilute acids, by pouring it in a thin stream into them. When pure, mercury pours from a glass surface without leaving a streak—*i. e.*, the single droplets retain their globular form, and do not form a tail or adhere to the glass.

Properties.—Mercury is the only metal which is liquid at ordinary temperatures. Its sp. gr. is 13.596. At —40° C. (—40°F.) it solidifies and crystallizes in octahedra. It is somewhat volatile at ordinary temperatures, and boils at 360° C. (680° F.). Its vapor has a density of 99.25 and a sp. gr. of 6.97 (air = 1). Its molecular weight, therefore, is 198.5; and as its atomic weight is also 198.5, its molecule, like that of cadmium, is composed of **one** atom. If pure, and at ordinary temperatures, it is not altered in the air, but at a temperature near the boiling point it becomes coated with a thin film of mercuric oxide. Hot sulphuric acid converts it into mercuric sulphate, with the evolution of sulphur dioxide. It dissolves readily in dilute nitric, but not in hydrochloric acid.

Mercury alloys with and dissolves all metals except iron, to form **amalgams.** Tin amalgam is used for coating mirrors.

Mercury forms two series of compounds, the mercurous and mercuric. The mercurous are less stable, and contain a larger percentage of the metal. They are less soluble, and consequently less poisonous.

Mercuric.	Mercurous.	Mercuric.	Mercurous.
HgO	Hg_2O	HgI_2	Hg_2I_2
HgS	Hg_2S	$Hg(NO_3)_2$	$Hg_2(NO_3)_2$
$HgCl_2$	Hg_2Cl_2	$HgSO_4$	Hg_2SO_4

Mercurous Compounds.—Mercurous chloride, protochloride, mild chloride, calomel, hydrargyri chloridum mite (U. S. P.), **hydrargyri subchloridum** (Br.), HgCl or Hg_2Cl_2. is usually prepared by the mutual decomposition of sodium chloride. mercuric sulphate, and mercury.. After mixing thoroughly in a mortar, the mixture is heated, when the calomel sublimes.

$$HgSO_4 + 2NaCl + Hg = Na_2SO_4 + Hg_2Cl_2.$$
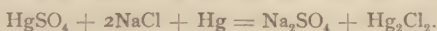
By this method mercuric chloride is also formed in varying quantities, and should be removed by washing the product with boiling distilled water, until the washings no longer form a precipitate with ammonium hydroxide.

Mercuric chloride may be detected in calomel by its forming a black stain upon a bright iron surface dipped in a mixture of calomel and alcohol; or by the production of a black stain by hydrogen sulphide in water that has been filtered through calomel so contaminated. Calomel crystallizes, when sublimed, in radiating, quadratic prisms; but if precipitated from solutions of mercurous salts by hydrochloric acid, it forms a heavy, white, impalpable, amorphous powder. Heated to about 500° C. (932° F.), it sublimes without fusing, is insoluble in cold water and alcohol, and dissolves in boiling water to the extent of 1 part in 12,000. If boiled for a long time with water, it partly decomposes, mercury being deposited and mercuric chloride passing into solution. Strong acids convert it into mercuric salts and free mercury. With ammonium hydroxide it blackens, with the formation of **mercurous amidogen chloride.**

$$Hg_2Cl_2 + 2NH_4OH = NH_4Cl + NH_2Hg_2Cl + 2H_2O.$$

Hydrochloric acid and alkaline chlorides convert it into mercuric chloride; this may occur in the stomachs of persons who use large quantities of salted food, as on board ship. Alkaline iodides convert it into mercurous iodide, which is then decomposed, by an excess of the alkaline iodides, into mercuric iodide and mercury.

Mercurous iodide, protiodide or **yellow iodide, hydrargyri iodidum flavum** (U. S. P.), HgI or Hg_2I_2, is prepared by triturating 200 parts of mercury with 127 parts of iodine and a little alcohol. until a green paste is formed. It may also be prepared by precipitation from a solution of $Hg_2(NO_3)_2$ with KI.

$$Hg_2(NO_3)_2 + 2KI = Hg_2I_2 + 2KNO_3.$$

It is a bright yellow, amorphous powder, insoluble in water and in alcohol. It turns brown and volatilizes when heated. Light decomposes it into mercuric iodide and mercury. When moderately heated.

it becomes red, but upon cooling it resumes again its yellow color. But when strongly heated it is decomposed into the red mercuric iodide and mercury.

Mercurous oxide, protoxide, or **black oxide,** Hg_2O, is formed by the action of sodium hydroxide upon mercurous salts.

$$Hg_2(NO_3)_2 + 2NaOH = Hg_2O + 2NaNO_3 + H_2O.$$
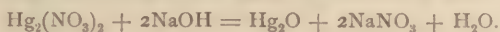
It is a brownish-black, tasteless powder, which sunlight decomposes into mercuric oxide and mercury. Mineral acids convert it into the corresponding mercurous salts. It exists in the **lotio hydrargyri nigri** (Br.), **lotio nigra** (N. F.), or **black wash.** This is made by adding calomel to lime-water, in the proportion of one drachm of calomel to one pint of lime-water.

$$Hg_2Cl_2 + Ca(OH)_2 = Hg_2O + CaCl_2 + H_2O.$$
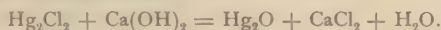
Mercurous nitrate, $HgNO_3$ or $Hg_2(NO_3)_2$, is formed by digesting an excess of mercury with a somewhat diluted nitric acid, until short prismatic crystals separate.

$$6Hg + 8HNO_3 = 3Hg_2(NO_3)_2 + 4H_2O + N_2O_2.$$
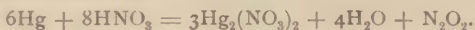
The crystals effloresce in the air. Water decomposes this salt into the acid salt, which goes into solution, and **basic mercuric nitrate,** $Hg \begin{smallmatrix} OH \\ NO_3 \end{smallmatrix}$, which separates as a yellow powder. Water acidulated with nitric acid dissolves it, but it soon oxidizes and becomes mercuric nitrate. By adding metallic mercury to the solution, this oxidation is prevented to a certain extent, or, after oxidation, it reduces it again to the **mercurous** state.

$$Hg(NO_3)_2 + Hg = Hg_2(NO_3)_2.$$
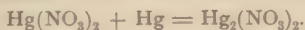
Mercurous sulphate, Hg_2SO_4, is formed by gently warming an excess of mercury with sulphuric acid. It separates as a yellow, crystalline precipitate when sulphuric acid is added to a solution of mercurous nitrate.

Mercuric Compounds.—In these, mercury is bivalent. They are represented by the formula HgR_2. The mercuric compounds are always formed when mercury is dissolved in an excess of acid. When the opposite is the case, the **ous** compounds are formed. The addition of metallic mercury to the mercuric compounds converts them into mercurous compounds, while oxidizing agents produce the opposite effect.

Mercuric chloride, bichloride, corrosive sublimate, hydrargyri chloridum corrosivum (U. S. P.), **hydrargyri perchloridum** (Br.), $HgCl_2$, may be produced by dissolving mercuric oxide in hydrochloric acid.

It is prepared on a large scale by subliming a dried mixture of mercuric sulphate and sodium chloride.

$$HgSO_4 + 2NaCl = HgCl_2 + Na_2SO_4.$$

When sublimed, it crystallizes in rectangular octahedra. When crystallized from its solutions, it forms fine, right rhombic, needle-like prisms. At ordinary temperatures it dissolves in sixteen parts of water, and at $100°$ C. ($212°$ F.) in three parts; it is still more soluble in alcohol. It dissolves freely in hot hydrochloric acid, which solution gelatinizes on cooling. Its sp. gr. is 5.4. In aqueous solution it tends to reduce to calomel. Sodium or ammonium chloride prevents this change. Zinc, cadmium, nickel, iron, lead, copper, and bismuth remove most of its chlorine, reducing it either to metallic mercury or calomel. Sulphuric, nitric, and hydrochloric acids all dissolve it without decomposition. When its aqueous solution is treated with an alkaline hydroxide, or alkaline earth, a yellow precipitate of mercuric oxide, HgO, is formed.

This is formed in **lotio flava** (N. F.), or **yellow wash**,—**aqua phagedænica** of the older writers,—which is made by mixing thirty grains of mercuric chloride with a pint of lime-water. Mercuric chloride prevents putrefaction. It is an excellent antiseptic, much used in surgical operations. Its solution is used for preserving and hardening anatomical specimens. With albumin, it forms a white precipitate, insoluble in water, but soluble in excess of albumin solution or in solutions of alkaline chlorides.

Mercurammonium chloride, white precipitate, ammoniated mercury, hydrargyrum ammoniatum (U. S. P., Br.), NH_2HgCl, is thrown down as a heavy, white precipitate, by adding a slight excess of ammonium hydroxide to a solution of mercuric chloride.

$$HgCl_2 + 2NH_4OH = NH_2HgCl + NH_4Cl + 2H_2O.$$

This salt is sometimes called "amidochloride of mercury," and may be looked upon as a compound of mercury, chlorine, and amidogen, NH_2.

Ammoniated mercury occurs in white, pulverulent pieces, or in powder. It has no odor, but an earthy, metallic taste. It is used in the official **unguentum hydrargyri ammoniati.** It is insoluble in alcohol, ether, and cold water. Hot water decomposes it, with the separation of a heavy yellow powder. It sublimes without fusing.

Mercuric iodide, biniodide, or **red iodide, hydrargyri iodidum rubrum** (U. S. P., Br.), HgI_2, is formed when solutions of mercuric chloride and potassium iodide are mixed.

$$HgCl_2 + 2KI = HgI_2 + 2KCl.$$

A double decomposition takes place, and the mercuric iodide separates as a yellow precipitate, which immediately turns bright red. It is sparingly soluble in water, but freely soluble in solutions of KI and alcohol, forming clear solutions. It also dissolves in many dilute acids, and in solutions of ammonium salts, alkaline chlorides, and mercuric salts. From its alcoholic solution it crystallizes in bright red, rhombohedral crystals. When heated, it becomes yellow, fuses, and sublimes in yellow, shining, rhombic needles. These again become red upon touching them with some solid, and are changed into a mass of octahedra. Mercuric iodide is, therefore, **dimorphous.** HgI_2 enters into the composition of Donovan's solution.

Mercuric oxide, red oxide or **binoxide, hydrargyri oxidum flavum** (U. S. P., Br.), **hydrargyri oxidum rubrum** (U. S. P., Br.), HgO, is obtained by igniting mercurous or mercuric nitrate as long as fumes are given off:

$$2Hg(NO_3)_2 = 2HgO + 2N_2O_4 + O_2 ;$$

or, by adding sodium hydroxide to a solution of a mercuric salt:

$$HgCl_2 + 2KOH = HgO + 2KCl + H_2O.$$
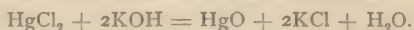
The product obtained by the first method is red and crystalline, of sp. gr. 11.2 ; that obtained by precipitation is yellow and amorphous, furnishing **hydrarg. oxid. flavum** (U. S. P.). The latter is the more active form. Both modifications turn black when exposed to the light and air. At 400° C. (752° F.) they break up into mercury and oxygen. Mercuric oxide is very sparingly soluble in water. It is the chief ingredient of the **lotio flava** (N. F.) and **lotio hydrargyri flava** (Br.), or **yellow wash.**

Mercuric nitrate, $Hg(NO_3)_2$, may be obtained by dissolving mercury or mercuric oxide in hot nitric acid.

$$HgO + 2HNO_3 = Hg(NO_3)_2 + H_2O.$$
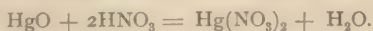
This should be carefully conducted, as it is inclined to form basic salts. It dissolves in water, and exists in the **liq. hydrargyri nitratis** (U. S. P.), or **liq. hydrargyri nitratis acidus** (Br.). It is used in the volumetric estimation of urea by Liebig's method. The standard solution used for this purpose contains 71.48 gm. of metallic mercury to the liter, and 1 c.c. precipitates 10 milligrams of urea.

Mercuric sulphate, hydrargyri persulphas (Br.), $HgSO_4$, is prepared by warming mercury or its oxide with an excess of sulphuric acid.

$$Hg + 2H_2SO_4 = HgSO_4 + SO_2 + 2H_2O.$$

It is a white, crystalline salt, used as the exciting agent in some forms

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of galvanic batteries.   With an excess of water it decomposes into sulphuric acid and the yellow, insoluble, basic salt, **turpeth mineral,** $HgSO_4 . 2HgO$.   This is official in the U. S. P. under the name **hydrargyri subsulphas flavus.**

Mercuric sulphide, red sulphide, cinnabar, vermilion, hydrargyri sulphuretum rubrum (U. S. P., 1880), HgS, occurs native in radiating or amorphous masses.   It may be prepared by rubbing sulphur and mercury together, or by the precipitation of a mercuric salt by hydrogen sulphide, as a black, amorphous mass, which is the **æthiops mineralis** of the older pharmacists.

$$HgCl_2 + H_2S = HgS + 2HCl.$$

This may be converted into the red sulphide by subliming it.   **Hydrargyri cyanidum,** $Hg(CN)_2$, is official.

Physiological Action of Mercury.—If introduced into the animal economy, metallic mercury is not poisonous.   By contact with alkaline chlorides, however, it is converted into mercuric chloride ; the more finely divided the particles of mercury are, the more readily does this take place.

Mercuric chloride has a decidedly toxic action, both locally and constitutionally.   Its local irritant action is due to its tendency to unite with albuminoid bodies.   The constitutional symptoms are somewhat similar to those produced by arsenic, but appear sooner.   The vomit frequently contains blood, and there is an intense burning, metallic taste in the mouth.   The symptoms that are referable to the gastro-intestinal mucous membrane are more intense.   The size of the minimum fatal dose of the corrosive chloride is about three grains ; of white precipitate, thirty to forty grains ; and of turpeth mineral, about forty grains.   Children tolerate mercury much better than adults.

The treatment in acute poisoning should consist in the administration of milk or white of egg and the induction of prompt emesis. Absorbed mercury probably exists in the blood as an albuminate, and is eliminated by the feces, urine, and saliva ; chiefly by the former. Chronic mercurial poisoning, known as **mercurial tremors, shaking palsy,** etc., is met with in those who work in mercury compounds. The symptoms usually begin with debility, nausea, vomiting, colicky pains, and a constant metallic taste in the mouth.   Sooner or later salivation will become a prominent symptom ; the tongue and gums becoming swollen, red, and ulcerated, and the breath emitting a peculiar, fetid odor.   Salivation may, however, be produced by bromine, antimony, lead, prussic acid, etc.

Chronic and even acute poisoning may occur from the free external

use of mercurial salts. **Postmortem**, the mucous membrane of the stomach, in acute poisoning with $HgCl_2$, is usually found of a grayish color, as also that of parts of the mouth and esophagus. The surface of the membrane is sometimes covered with a slate-colored deposit of finely divided mercury.

Tests.—One of the simplest tests for mercury in solution is a piece of bright copper, which, in the presence of a small quantity of free hydrochloric acid, becomes coated with a silver-white layer of copper amalgam. All salts of mercury are volatile. When heated in a tube with sodium carbonate, globules of metallic mercury distil off from all its salts. Mercury salts give a black precipitate with H_2S, which is insoluble in nitric acid, but soluble in aqua regia.

GROUP IV.

Boron,	$B = 11.$	Indium,	$In = 113.7.$
Aluminum,	$Al = 27.$	Lanthanum,	$La = 138.2.$
Scandium,	$Sc = 44.$	Erbium,	$E = 166.$
Gallium,	$Ga = 69.$	Ytterbium,	$Yb = 173.$
Yttrium,	$Y = 89.1.$	Thallium,	$Th = 204.18.$

Of the above elements, but the first two are of sufficient interest to be described here.

BORON.

$$B = 11.$$

Occurrence and Preparation.—An unimportant element, never occurring native, but as boric acid and borates. Borates of calcium, magnesium, and sodium (borax) occur native; the last, the most important, is found in India and California. The element may be prepared in two allotropic states: the first, as a greenish-brown powder, by fusing its oxide with sodium or potassium; the second, as a crystalline, transparent solid, varying in color from colorless to a garnet-red, by fusing the oxide, chloride, or fluoride with aluminum. Boron combines directly with nitrogen at elevated temperatures.

Boric anhydride, B_2O_3, is a transparent, glass-like mass, obtained by heating boric acid to redness. It is used as a reagent in blowpipe analysis.

Boric acid, boracic acid, acidum boricum (U. S. P., Br.), H_3BO_3, exists native in lagoons, in the vicinity of volcanoes, especially in Tuscany. By evaporation and crystallization the acid is obtained. **Borate of sodium,** or **borax,** occurs in California and India, and from it the pure acid is prepared by precipitating it with HCl from a hot solution.

$$Na_2B_4O_7.10H_2O + 2HCl = 2NaCl + 4H_3BO_3 + 5H_2O.$$
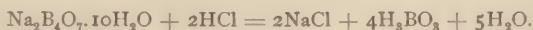
The acid separates in white, shining scales. California and Nevada furnish enough borax to supply the entire American market. Boric acid is soluble in 25 parts of H_2O at 14° C. (57.2° F.) and in 3 parts of boiling H_2O. The solution has a faint acid reaction. The acid is soluble in 15 parts of alcohol, and is also soluble in glycerin, to the flame of both of which it imparts a distinct green color; this, and the action on turmeric paper, are used as tests. If a strip of turmeric paper be dipped in a solution containing H_3BO_3, it turns reddish-brown on drying.

When boiled with glycerin, an ether is formed, known as **boroglycerid,** which is soluble in water, has a neutral reaction, is tasteless, and is used as a preservative for foods. Its use in considerable doses, as well as that of boric acid, is attended with an increased excretion of urea, irritation of the kidneys, and should, therefore, be used with some caution. Owing to its antiseptic action, it is used in surgical dressings.

Glyceritum boroglycerini (U. S. P.) is made by dissolving thirty-one per cent. of boric acid in glycerin, with the aid of heat.

When heated, H_3BO_3 loses one molecule of water at 100° C. (212° F.), and forms **metaboric** acid, HBO_2; on further heating it forms **tetraboric** acid, $H_2B_4O_7$; and at a higher temperature **boric anhydride,** B_2O_3.

Boric acid is used as a mild antiseptic and detergent. It is often used in applications to the mucous membranes, in eye-washes, and in internal cavities.

Boric acid and its salts are usually poisonous to lower animals and plants. Fatal cases of poisoning have been recorded. Serious symptoms of great depression of spirits, low temperature, feeble pulse, nausea and vomiting, hiccup, embarrassed respiration, etc., have followed the too free use of boric acid. It is generally rapidly eliminated in the urine.

ALUMINUM (Aluminium).

$$Al = 27.$$

This metal is found very widely distributed. It exists as oxide in **ruby, sapphire,** and **corundum,** and, less pure, in **emery.** Most commonly, it occurs as the silicate (clay, kaolin), and with other silicates, as **feldspar** and **mica,** and in many crystalline rocks. Emerald is a silicate of aluminum and glucinum. Garnet and topaz are also silicates of aluminum.

Cryolite is a double fluoride of aluminum and sodium.

Preparation and Properties.—Aluminum may be obtained in the metallic condition by igniting the chloride or the double fluoride of sodium and aluminum with sodium.

$$2Na_3AlF_6 + 3Na_2 = Al_2 + 12NaF.$$
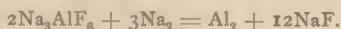
It is now generally manufactured by the electrolysis of a mixture of cryolite, Na_3AlF_6, and aluminum oxide. The mixture fuses and then decomposes, giving almost chemically pure aluminum. Since the introduction of this method of manufacture the price of the metal has greatly decreased and its use greatly increased.

It is a silver-white metal, very malleable and ductile, a good conductor of electricity; sp. gr., 2.56. At ordinary temperatures it is not affected by air or oxygen. When heated in an atmosphere of oxygen, it burns like iron and some other metals. It is insoluble in nitric acid, but soluble in boiling sulphuric and cold hydrochloric acids. It dissolves in alkaline hydroxides to form **aluminates,** with the liberation of hydrogen It forms a hard and durable alloy with copper, known as alumi 1e^{nu}bronze.

Aluminum chloride, Al_2Cl_6, is obtained by the action of chlorine upon heated aluminum. It forms colorless, hexagonal prisms, fusible, volatile, and very soluble in water and alcohol. It crystallizes from a hot concentrated solution with $12H_2O$.

Aluminum oxide, alumina, Al_2O_3, is found crystallized in prisms, and colored by other admixtures, in **ruby, sapphire,** and **corundum.** These minerals are all exceedingly hard, ranking next to the diamond in this respect. Alumina may be obtained artificially, by igniting the hydroxide, as a light, white, insoluble, odorless, and tasteless powder. When prepared as above, acids attack it with great difficulty. It may be decomposed by fusing with caustic alkalies or acid potassium sulphate.

Aluminum hydroxide, $Al_2(OH)_6$, is formed by precipitating a solution of an aluminum salt with ammonium hydroxide or carbonate.

Alumini hydras (U. S. P.) is prepared by precipitating a solution of alum with sodium carbonate.

$$K_2Al_2(SO_4)_4 + 3Na_2CO_3 + 3H_2O = 3Na_2SO_4 + K_2SO_4 + Al_2(OH)_6 + 3CO_2.$$
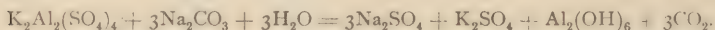
When freshly precipitated, it is insoluble in water, but soluble in solutions of the fixed alkalies. By prolonged drying, or after standing under water, it is rendered almost insoluble in acids, although it undergoes no apparent change in composition or form.

Aluminum sulphate, alumini sulphas (U. S. P.), $Al_2(SO_4)_3$. $16H_2O$, is prepared artificially by the action of sulphuric acid upon kaolin or clay, and also by dissolving aluminum hydroxide in the same acid.

$$Al_2(OH)_6 + 3H_2SO_4 = Al_2(SO_4)_3 + 6H_2O.$$
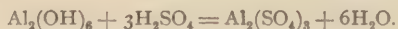
It crystallizes in thin plates with $16H_2O$; soluble in water and sparingly so in alcohol. When heated, it fuses and becomes anhydrous.

Alums.—These are double salts formed by the combination of aluminum sulphate with the alkaline sulphates. The salt originally known as **alum** is the double sulphate of aluminum and potassium, $K_2Al_2(SO_4)_4.24H_2O$. It is obtained from clays free from iron, and from **aluminite,** a basic sulphate of aluminum. The potassium in this alum can be replaced by sodium, ammonium, rubidium, cesium, and thallium. **Potassium alum, alumen** (U. S. P., Br.), K_2SO_4.-$Al_2(SO_4)_3.24H_2O$, forms large, regular, transparent, octahedral crystals, soluble in water. Heated to about redness, it loses forty-five per cent. of its weight of water, forming the product known as **burnt alum,** or **alumen exsiccatum** (U. S. P., B-). Thus prepared, it is a dry, white powder, having a strong affin to r water. **Aluminum and ammonium sulphate, or ammonia alum,** $Al_2(SO_4)_3.(NH_4)_2SO_4$.-$24H_2O$, is rapidly taking the place of the potassium alum, from which it differs in being more soluble in water between 20° C. (68° F.) and 90° C. (104° F.), and less soluble in water colder or warmer than this. Ammonia alum is included in the British Pharmacopœia. At about the temperature at which potash alum loses its water, ammonia alum decomposes, losing its ammonia. Ferric iron, manganese, and chromium may replace the aluminum in alum and form a series of alums known as **ferric alum,** $Fe_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$, **manganese alum,** $Mn_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$, and **chrome alum,** $Cr_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$.

Uses.—Alum is an astringent and styptic. It is used as a mordant in calico printing, in dyeing, and to produce aluminum lakes, used as pigments.

METALS OF GROUP V.

Vanadium,	$V = 51.$
Columbium,	$Cb = 94.$
Neodymium,	$Nd = 140.5.$
Praseodymium,	$Pr = 143.5.$
Tantalum,	$Ta = 182.6.$

They are all rare metals, not used in medicine.

METALS OF GROUP VI.

Chromium,	$Cr = 52.1.$
Molybdenum,	$Mo = 96.$
Wolfram (Tungsten),	$W = 184.9.$
Uranium,	$U = 239.6.$

Of these, chromium and molybdenum will be noticed at length.

CHROMIUM.

$Cr = 52.1.$

Occurrence, Preparation, and Properties.—This metal most commonly occurs in chromite, or chrome iron-ore, a ferrosochromic oxide; also, rarely, as lead chromate. It may be isolated with difficulty from its oxide by reducing it with charcoal, or from the chloride by reducing with zinc. It is a hard, glistening, steel-gray metal, magnetic at low temperatures; sp. gr., 6.8. It oxidizes only at a red heat, and is soluble in hydrochloric acid and strong alkalies.

Chlorides.—Two chlorides are known: **chromous chloride,** $CrCl_2$, a white, crystalline solid, dissolving in water to form a blue solution; and **chromic chloride,** Cr_2Cl_6, occurring in large, red crystals, insoluble in water, unless a trace of the chromous chloride be present, when it readily dissolves. If it be subjected to a prolonged boiling with water, it finally dissolves, forming a green solution containing a hydroxide. An oxychloride is also known.

Chromic Anhydride, Chromic Trioxide.—CrO_3. This is sometimes improperly called chromic acid. It is prepared by adding

one and one-half parts of strong sulphuric acid to one part of concentrated solution of potassium dichromate. When the solution cools, splendid saffron-colored needles of the trioxide crystallize out, which may be dried on a porous tile. It is a powerful oxidant, igniting alcohol if the latter be poured upon it. It is used in medicine as a caustic, forming a superficial eschar.

Chromic oxide, chromium sesquioxide, green oxide, Cr_2O_3, is obtained by calcining a mixture of starch and potassium dichromate. Thus prepared, it is a green powder, insoluble in water, acids, or alkalies, and fusible with difficulty. When fused with alkaline hydroxides or nitrates, it forms chromates of these metals.

This oxide may play either a positive or a negative rôle, depending upon the oxide with which it unites. For example, with the strongly negative sulphuric oxide it forms chromium sulphate, $Cr_2(SO_4)_3$; while with calcium or magnesium oxide, calcium or magnesium chromates are obtained, $CaCrO_4$, or $MgCrO_4$.

Chromous Hydroxide.—$Cr(OH)_2$. This compound is produced by precipitating chromous chloride with potassium hydroxide. It acts as a basic oxide, yielding chromous salts.

Chromic Acid.—H_2CrO_4. This can not be isolated, but by solution of chromium trioxide in water an acid liquid is obtained containing chromic acid. This acid decomposes on evaporation.

The best known of the salts of this acid are potassium chromate and dichromate, K_2CrO_4 and $K_2Cr_2O_7$. The last of these possesses the properties of the trioxide, but in a milder degree. It is sometimes used as an escharotic, but much more frequently as an oxidizing agent, when mixed with sulphuric acid. None of the other preparations of chromium are used in medicine. Internally, in large doses, it acts as an irritant poison.

Chromic sulphate, $Cr_2(SO_4)_3$, is obtained by dissolving chromic oxide in sulphuric acid; upon slowly evaporating, it crystallizes with twelve molecules of water.

Chromium salts form two series, the one green and the other violet. The alkaline hydroxides throw down a bluish-green hydroxide from the green salts, and a violet from the violet salts.

Chromium sulphate exists as a violet, crystalline solid, and as a green, amorphous solid. With the alkaline sulphates, chromium sulphate forms double salts—the chromium alums. (See p. 286.)

Potassium chromate, K_2CrO_4, is obtained by adding a solution of potassium hydroxide to one of potassium dichromate.

$$K_2Cr_2O_7 + 2KOH = 2K_2CrO_4 + H_2O.$$
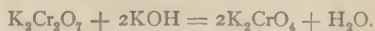
It forms large, yellow, rhombic crystals, isomorphous with potassium sulphate, K_2SO_4.

Potassium dichromate, $K_2Cr_2O_7$, commercially known as the **red chromate of potash,** and often called the acid potassium chromate, is obtained by igniting pulverized **chromite,** $Cr_2O_3.FeO$, with potassium carbonate and nitrate, forming potassium chromate and ferric oxide. The potassium chromate is dissolved out with water, and nitric or acetic acid added to the solution, from which potassium dichromate crystallizes. It forms large, red prisms, soluble at ordinary temperatures in ten parts of water. When it is warmed with sulphuric acid, oxygen escapes and chromic oxide is produced ; and on standing, potassium chrome alum is formed.

$$K_2Cr_2O_7 + 4H_2SO_4 = K_2SO_4.Cr_2(SO_4)_3 + O_3 + 4H_2O.$$
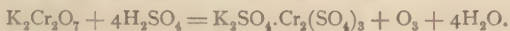
When potassium dichromate is heated alone, it gives off oxygen.

$$2K_2Cr_2O_7 = 2K_2CrO_4 + Cr_2O_3 + O_3.$$

When heated with HCl, it gives off chlorine.

$$K_2Cr_2O_7 + 14HCl = 2KCl + Cr_2Cl_6 + 7H_2O + 3Cl_2.$$
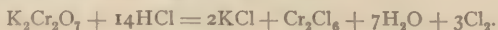
It will be seen from these reactions how it may be utilized as an oxidizing agent.

A mixture of H_2SO_4 and $K_2Cr_2O_7$ is employed in laboratories for oxidizing purposes.

Barium chromate, $BaCrO_4$, and lead chromate, $PbCrO_4$, are used as yellow pigments, the former under the name of *yellow ultramarine* and the latter as *orange chrome*.

Toxicology.—The chromates, especially potassium dichromate, are irritant poisons. They are also liable to produce a form of chronic poisoning in workmen handling them, characterized by ulceration of the septum of the nose and excoriations of the skin. The most prominent symptoms in acute poisoning are vomiting, epigastric pain, cramps, excessive thirst, and collapse. The treatment consists in the use of emetics, followed by magnesium carbonate in milk.

MOLYBDENUM.

$Mo = 96.$

This element is of little importance itself, but some of its compounds are used.

Molybdic Trioxide or Anhydride.—MoO_3. This oxide is obtained by roasting the native sulphide in an open vessel at a red heat. The principal interest attached to it is its use in preparing **ammo-**

25

nium molybdate, a reagent used to detect and estimate phosphoric acid, and which will be mentioned as a reagent for alkaloids.

The impure oxide obtained by roasting the mineral **molybdenite,** MoS_2, is dissolved in ammonium hydroxide, evaporated to dryness, redissolved in water, concentrated by evaporation, and allowed to crystallize. The soluble molybdates give a precipitate of MoO_3 on the addition of an acid ; but it is soluble in **excess** of the acid. The molybdates give a white precipitate with the earthy metals. With phosphoric acid or the phosphates, a solution of ammonium molyb- date containing an excess of nitric acid first turns yellow, then deposits a yellow precipitate of molybdic trioxide, phosphoric acid, and am- monia, which is very soluble in ammonia water. This is a very deli- cate test for phosphoric acid. Pyrophosphates and metaphosphates do not give this reaction. **Arsenic acid** gives a similar precipitate. **Phosphomolybdic acid,** $(H_3PO_4)_2 . 22MoO_3$, is employed as a re- agent for alkaloids. It may be prepared by digesting molybdic trioxide with phosphoric acid until a clear solution is obtained. When this solution is evaporated to dryness, a tenacious, non-crystal- line mass, very soluble in water and alcohol results.

The reagent usually employed is a ten per cent. solution in water.

TUNGSTEN (Wolfram).

$$W = 184.9.$$

Tungsten is not abundant. It occurs in the minerals **wolframite, schulite,** and **stolzite,** all of which are tungstates. Although gen- erally regarded as a metal, it often plays the negative rôle to form tungstic acid and tungstates.

The element is a hard, brittle, difficultly fusible metal, permanent in the air, but burns to the oxide at a red heat. Of the compounds of tungsten, the sodium tungstate alone is of interest to the medical student.

Tungstic acid, H_2WO_4, is a yellowish-white powder thrown down from boiling alkaline solutions of tungstic oxide by mineral acids. It forms with bases numerous salts, called tungstates, the most impor- tant of which is sodium tungstate, $Na_2WO_4 . 2H_2O$. This has recently attained considerable importance as a test for albumin in urine. A cold, saturated solution of this salt, added to acid solu- tions of the proteids, coagulates them. This salt is also used to render fabrics uninflammable.

Phosphotungstic acid is very much used as a reagent for pep- tones and alkaloids. The reagent is usually prepared from sodium

tungstate by adding to a hot solution of this salt enough phosphoric acid to make it decidedly acid. It is then cooled. made strongly acid with HCl, allowed to stand twenty-four hours, and filtered.

GROUP VII. METALS.

MANGANESE.

$Mn = 55$.

Occurrence.—Manganese is found widely distributed in nature. It occurs native in meteorites. Its most common ores are **pyrolusite**, MnO_2; **hausmannite**, Mn_3O_4; **braunite**, Mn_2O_3; **manganite**, $Mn_2O_3.H_2O$; and **rhodochrosite**, $MnCO_3$.

Preparation and Properties.—It is obtained in the metallic condition by heating its oxides with charcoal, similar to the smelting of iron. It is a grayish-white, brittle metal, very hard, and fusing with great difficulty; sp. gr., 7.2. Pure manganese has found little use in the arts. **Spiegeleisen** and **ferromanganese** are alloys with iron, containing carbon, which are used in making steel. Like the elements iron and chromium, it forms three series of compounds—the manganous, MnR_2; manganic, Mn_2R_6; and the salts of manganic acid, called **manganates**.

Manganous Compounds.—In these the metal is diatomic. These derivatives are the most stable, and constitute the most common of the manganese salts. They resemble the **ous** salts of iron and chromium, with which they are isomorphous. **Manganous oxide**, MnO. results from the ignition of the carbonate, with the exclusion of air. It is a greenish, amorphous powder, readily oxidizing in the air to Mn_3O_4. **Manganous hydroxide**, $Mn(OH)_2$, is formed by adding alkaline hydroxides to manganous solutions, as a reddish-white precipitate, which, exposed to the air, oxidizes to manganic hydroxide, and turns brown in color.

Manganous Salts.—**Manganous chloride**, $MnCl_2$. occurs in rose-colored, tabular crystals, which decompose on drying, with the separation of hydrochloric acid. **Manganous sulphate, mangani sulphas** (U. S. P.), $MnSO_4$, crystallizes at ordinary temperatures with $4H_2O$. It occurs as colorless or pale rose-colored, prismatic crystals, soluble in 0.8 part of water at 15° C. (59° F.) and in one

part of boiling water. With the alkaline sulphates it forms double salts—*e. g.*, $MnSO_4.K_2SO_4.5H_2O$. **Manganous carbonate,** $MnCO_3$, is precipitated from manganous solutions by alkaline carbonates as a white powder, turning brown on exposure to the air. **Manganous sulphide,** MnS, occurs in nature as **alabandite,** or manganese blende, and is precipitated from manganous solutions by alkaline sulphides as a flesh-colored hydrate, $MnS.H_2O$. In the air it also becomes brown.

Manganic Compounds.—These are isomorphous with and very closely resemble the ferric, chromic, and aluminic compounds. They are not so stable, however, being easily reduced to the manganous state. In them manganese is a tetrad.

Manganese dioxide, manganic peroxide, black oxide of manganese, mangani dioxidum (U. S. P., Br.), MnO_2, occurs native as the mineral **pyrolusite,** the principal ore of manganese, in steel-gray or brownish, imperfectly crystallized masses. It is official, and is used internally.

When strongly heated, it yields oxygen ; at a red heat it yields more oxygen, and forms manganous-manganic oxide.

$$3MnO_2 = Mn_3O_4 + O_2.$$

It gives off oxygen when heated with sulphuric acid, and forms manganous sulphate. With hydrochloric acid, it yields manganous chloride, water, and chlorine.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

It dissolves in cold hydrochloric acid without setting free chlorine, probably forming $MnCl_4$, which, upon heating, breaks up into $MnCl_2$ and Cl_2. From this it would appear that, in the dioxide, manganese is a tetrad.

Manganic oxide, Mn_2O_3, is a black powder, produced by igniting the manganese oxides in a current of oxygen.

Manganous-manganic Oxide.—$Mn_3O_4 = MnO.Mn_2O_3$. This is formed by the ignition of all the oxides in the air ; it is isomorphous with **magnetite,** Fe_3O_4.

Manganic hydroxide, $Mn_2(OH)_6$, is precipitated from solutions of manganic salts by ammonium hydroxide as a flesh-colored precipitate, rapidly turning brown.

Manganic sulphate, $Mn_2(SO_4)_3$, is produced by the action of sulphuric acid upon manganic hydroxide.

Manganates and Permanganates.—The derivatives of manganic acid, H_2MnO_4, or $MnO_2(OH)_2$, are analogous to those of ferric, H_2FeO_4, chromic, H_2CrO_4, and sulphuric acids, H_2SO_4. In these

derivatives manganese is a hexad. The manganates are of little permanency and little used.

Potassium manganate, K_2MnO_4, is a rare substance, isomorphous with potassium sulphate or chromate, and is very readily converted into potassium permanganate.

Potassium permanganate, potassii permanganas (U. S. P., Br.), $K_2Mn_2O_8$ or $KMnO_4$, is precipitated from solutions of potassium manganate by acids, in dark-red rhombic prisms. It is made by boiling a mixture of potassium hydroxide, potassium chlorate, and manganese dioxide with water, evaporating to dryness, and fusing.

$$6KOH + KClO_3 + 3MnO_2 = 3K_2MnO_4 + KCl + 3H_2O.$$

A greenish-colored mass—potassium manganate—is formed. This is dissolved in water, and is then easily decomposed by an acid or a large quantity of hot water.

$$3K_2MnO_4 + 3H_2O = K_2Mn_2O_8 + MnO_2 + 4KOH + H_2O.$$
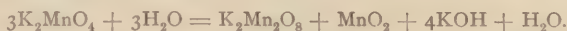
Manganese dioxide is precipitated, and the permanganate remains in solution, from which it is obtained by crystallization. This salt has active oxidizing properties, and is very largely used for oxidizing and destroying organic substances. It also converts ferrous into ferric salts, and is used for the quantitative estimation of ferrous salts because of this property. It is also used to estimate organic matter in potable waters.

Condy's fluid is an aqueous solution of $K_2Mn_2O_8$.

GROUP VIII.

The members of the group are:

Iron (Ferrum),	Fe = 56.	Rhodium,	Rh = 103.
Nickel,	Ni = 58.7.	Palladium,	Pd = 106.5.
Cobalt,	Co = 59.5.	Iridium,	Ir = 193.1.
Ruthenium,	Ru = 101.6.	Osmium,	Os = 190.8.
	Platinum, Pt = 195.		

Of these, iron, nickel, cobalt, osmium, and platinum are of sufficient interest to be given a place here.

IRON.

$Fe = 56.$

Occurrence.—This metal, which is of great practical importance, is distributed very widely in nature. It occurs native upon the earth's surface only as meteorites.

The ores from which iron is obtained are numerous ; the most important are : **magnetite,** Fe_3O_4 ; **hematite,** Fe_2O_3 ; **limonite** (ferric hydroxide) ; and **siderite,** $FeCO_3$. These are almost the only ores used for the manufacture of iron ; the sulphur ores are not adapted to this purpose.

Preparation.—In some cases the ore is first roasted, to get rid of water, carbon dioxide, sulphur, etc. The next step consists in the extraction of the iron from the ores, in which it exists as an oxide. This is accomplished by reduction with carbon at a glowing heat. This reduction is effected in a **blast furnace** (Fig. 59), of which the interior has the shape of a double cone. It is about fifty or sixty feet high, by fifteen feet wide at its widest part, is built of the most infusible fire-brick, and inclosed in solid masonry. It is filled at the top with alternate layers of coal, broken ore (either native or previously roasted), and fluxes in the form of limestone or silicates. These fluxes facilitate the melting together of the reduced iron, and furnish a liquid slag. The air necessary for combustion, usually heated to a high temperature beforehand, is forced into the bottom of the furnace, through pipes, by blowers or fans. The metal is drawn off at the bottom. In the lower part of the furnace carbon dioxide is produced from the oxygen of the air and the coal ; higher up, carbon monoxide is produced, which acts upon the oxide of iron, reducing it to the metallic state. As the reduced iron sinks, it comes into contact with the coal, takes up a small quantity of carbon, and forms cast-iron, which, on further sinking, fuses, and is drawn off into molds made in sand, to form **pig-iron.** The earthy impurities of the ores remaining in the furnace unite with the fluxes, fuse in the intense

FIG. 59.—BLAST FURNACE.

heat, and are drawn off as **slag.** The pig-iron is then subjected to the **puddling process,** by which it is more completely freed from carbon and slag, and **wrought-iron** results. This process is usually carried on in reverberatory furnaces with a free supply of air, while the half-molten mass is being thoroughly stirred. The greater part of the carbon is in this way burned into carbon monoxide, and the silicon, sulphur, and phosphorus oxidized. **Steel** was formerly prepared from wrought-iron only, by **cementation,** or heating wrought-iron packed in leather shavings or with charcoal. At present it is chiefly prepared directly from cast- or pig-iron by the method invented by Bessemer in 1850. This process consists in blowing air, under high pressure, into a mass of molten cast-iron until the carbon has been burned out, when spiegeleisen, containing a known quantity of carbon, is added to give the proper amount for steel. **Pure iron** is obtained by heating ferric oxide in a current of hydrogen ; this is the **ferrum reductum** of the U. S. P., Br.

$$Fe_2O_3 + 3H_2 = 3H_2O + Fe_2.$$
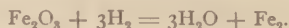
Properties.—Pure iron is soft, fuses at about 1600° C. (2912° F.), and has a sp. gr. of 7.25 to 7.9. Iron is not affected by dry air at ordinary temperatures ; in moist air it covers itself with a thin layer of ferric hydroxide, known as **rust.** Heated strongly in the air, it becomes coated with a layer of ferrous-ferric oxide, Fe_3O_4, which is readily loosened, forming the blacksmiths' scales. At a red heat it decomposes water, with the formation of ferrous-ferric oxide and the liberation of hydrogen.

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

It burns in oxygen with an intense, scintillating light. If brought into contact with a magnet, iron becomes magnetic. Tempered steel is the only form, however, that retains the magnetism.

Iron unites directly with chlorine, bromine, iodine, sulphur, and the members of the phosphorus group, except nitrogen. It dissolves readily in hydrochloric and sulphuric acids, with the evolution of hydrogen. In dilute nitric acid it dissolves, with the separation of nitric oxide. Concentrated nitric acid, however, renders it **passive,** when it is no longer attacked by the diluted acid, until the passive condition is destroyed by contact with silver, platinum, or copper, or by heating to 40° C. (104° F.).

Ferrous Compounds.—These are formed by dissolving iron in an acid, or by the reduction of ferric salts.

$$Fe_2Cl_6 + Zn = (FeCl_2)_2 + ZnCl_2.$$
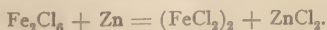
They are usually of a green color in the hydrous state. Exposed to the air, they oxidize to ferric salts.

$$4FeO + O_2 = 2Fe_2O_3.$$
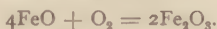
Ferrous chloride, $FeCl_2$, is formed when iron is dissolved in hydrochloric acid. It crystallizes in green monoclinic prisms, containing four molecules of water. Exposed to the air, they deliquesce and oxidize, forming ferric chloride and an oxychloride. The anhydrous chloride which is formed by passing hydrochloric acid gas over iron that is heated to redness is a volatile, yellowish-white, very soluble solid.

Ferrous iodide, ferri iodidum (Br.), FeI_2, is obtained in solution by adding an excess of iron to iodine suspended in warm water until the solution is pale green.

Ferri iodidum saccharatum (U. S. P.), **saccharated ferrous iodide,** is made by reacting upon iron with iodine in the presence of water, evaporating the solution to dryness, and mixing with sugar of milk.

Syrupus ferri iodidi is also official. It contains about 10 per cent. of FeI_2.

Ferrous oxide, FeO, is a black powder produced by the reduction of ferric oxide by carbon. It easily oxidizes again.

Ferrous hydroxide, $Fe(OH)_2$, is precipitated from ferrous solutions, by alkaline hydroxides, as a white gelatinous precipitate. It also readily oxidizes, becoming green, and then brown.

Ferrous sulphate, protosulphate of iron, green vitriol, copperas, ferri sulphas (U. S. P., Br.), $FeSO_4.7H_2O$, is obtained pure by dissolving iron in dilute sulphuric acid.

$$Fe + H_2SO_4 = FeSO_4 + H_2.$$

The commercial salt is obtained from **pyrites,** FeS_2, by oxidation, and as a by-product in other processes. It forms oblique rhombic prisms. At a red heat it decomposes into ferric oxide and sulphur di- and trioxides. On this property is based the production of fuming or **Nordhausen sulphuric acid**.

Green vitriol has an extended use in the arts. Among other uses, it is employed in the manufacture of ink, and as a mordant in dyeing.

Ammonio-ferrous sulphate, $FeSO_4.(NH_4)_2(SO_4)_2.6H_2O$, is a green, crystalline salt resembling the sulphate. It is more stable than ferrous sulphate.

Ferrous carbonate, $FeCO_3$, exists in the mineral **siderite.** It may be obtained by adding sodium carbonate to ferrous solutions.

$$FeSO_4 + Na_2CO_3 = FeCO_3 + Na_2SO_4.$$

It is rapidly changed to ferric hydroxide on exposure to the air ; is insoluble in pure water, but soluble in water containing carbon dioxide, and is, therefore, present in many natural waters.

Ferri carbonas saccharatum (U. S. P.) is a mixture of ferrous carbonate and sugar. It is prepared by mixing solutions of ferrous sulphate and sodium bicarbonate, and adding sugar : the mixture is then evaporated to dryness. It is a greenish-gray powder. The sugar is added to prevent oxidation of the $FeCO_3$.

Ferrous phosphate, triferrous phosphate, $Fe_3(PO_4)_2$, is a white precipitate formed by adding sodium phosphate to a solution of a ferrous salt. It turns blue on exposure to the air, a part being converted into ferric phosphate. It is insoluble in pure water, but slightly soluble in water containing carbon dioxide or acetic acid. A soluble or acid phosphate, **ferri phosphas solubilis**, is official. A phosphate of iron that turns blue on exposure to the air exists in the lungs in phthisis, in bones which have been buried for some time, and occasionally in pus.

Ferrous sulphide, protosulphide, FeS, may be obtained, first, by fusing a mixture of sulphur and iron filings, although the union will often occur slowly at ordinary temperatures ; second, by the precipitation of a ferrous salt with alkaline sulphides. The first method forms brownish, brittle, fusible masses ; the latter yields a black powder. Ferrous sulphide is not decomposed by heat, but is decomposed by sulphuric acid, with the formation of ferrous sulphate and hydrogen sulphide. It occurs in the feces of persons taking chalybeate waters and preparations of iron.

Ferrous lactate, ferri lactas (U. S. P.), $Fe(C_3H_5O_3)_2 \cdot 3H_2O$, is obtained by dissolving iron filings in lactic acid. It forms light yellow crystals, soluble in water and insoluble in cold alcohol.

Ferrous oxalate, FeC_2O_4, is made by dissolving iron in a solution of oxalic acid. It is a bright yellow, crystalline powder, slightly soluble in hot water.

Ferrous tartrate, $FeC_4H_4O_6$, is formed by dissolving iron in a hot, strong solution of tartaric acid.

Ferric Compounds.—Ferric chloride, sesquichloride of iron, perchloride of iron, ferri chloridum (U. S. P.), Fe_2Cl_6, may be obtained in anhydrous, volatile, deliquescent plates by heating iron in chlorine gas. It may be formed in solution by dissolving iron in hydrochloric acid and adding a little chlorine water or nitric acid ; or by dissolving the oxide or hydroxide in hydrochloric acid ; or by the action of chlorine on a solution of ferrous chloride. To obtain the solid, it is only necessary to evaporate and crystallize.

It forms yellow, crystalline masses or rhombic plates, readily soluble in water, alcohol, or ether.

The **liquor ferri chloridi** (U. S. P.), or **liquor ferri per-chloridi fortior** (Br.), is an aqueous solution containing an excess of acid.

The U. S. P. preparation contains 37.8 per cent. of ferric chloride, and the Br. preparation 58 per cent.

The **tinct. ferri chloridi** (U. S. P.) is the same, diluted with alcohol, and contains also ethyl chloride and ferrous chloride. It contains about 13.6 per cent. of Fe_2Cl_6. **Tinct. ferri perchloridi** (Br.) contains 14.5 per cent. of Fe_2Cl_6.

Ferric oxide, sesquioxide of iron, Fe_2O_3, exists in nature as hematite, and may be formed by heating the oxygen compounds of iron in the air. On a large scale, it is obtained by distilling ferrous sulphate, which first turns white, from loss of water; then yellow, owing to the formation of a basic hydroxide, and finally to a brick-red ferric oxide. It is used as a polishing material, under the names of **colcothar, red crocus, jeweler's rouge,** or **caput mortuum.**

Ferrous-ferric oxide, $Fe_3O_4 = FeO.Fe_2O_3$, occurs native as **magnetite.** It may be obtained artificially by conducting steam over ignited iron. It constitutes the natural magnets, or **magnetite.**

Ferric hydroxide, ferri oxidum hydratum (U. S. P.), **ferri peroxidum hydratum** (Br.), $Fe_2(OH)_6$, is a voluminous, reddish-brown, gelatinous mass, precipitated by alkaline hydroxides from ferric solutions. When dried at 100° C. (212° F.), it loses $2H_2O$. Freshly precipitated ferric hydroxide is soluble in a solution of ferric chloride or acetate, and if such a solution be dialyzed, the iron salt diffuses, leaving the pure ferric hydroxide on the dialzyer. The **dialyzed** iron so obtained is coagulated by heat, acids, or alkalies into a jelly-like mass. It is a good antidote in arsenic-poisoning. (See p. 195.)

Ferric sulphate, $Fe_2(SO_4)_3$, is obtained by dissolving the oxide in sulphuric acid. It remains, after evaporating the solution, as a white mass, which dissolves readily in water, forming the **liquor ferri tersulphatis** (U. S. P.), **liquor ferri persulphatis** (Br.). This solution is a dark, reddish-brown liquid, having an acid, styptic taste. Another sulphate, which is basic, is formed by treating ferrous sulphate, 77 parts, with nitric acid, and evaporating after adding 7 parts sulphuric acid.

This, in solution, is the **liquor ferri subsulphatis,** or **Monsel's solution,** $Fe_4O(SO_4)_5$.

Ferric alum, ammonio-ferric alum, ferri et ammonii sulphas (U. S. P.), $(NH_4)_2Fe_2(SO_4)_4.24H_2O$, is prepared by adding a solution of ammonium sulphate to a solution of ferric sulphate, and evaporating down and allowing it to crystallize. The crystals

are colorless to pale amethyst, regular octahedra, soluble in 3 parts of water at 15° C. (59° F.). The solution has an acid reaction and an astringent taste, but not so astringent as ferric sulphate. It gives the reactions for ferric iron, ammonia, and sulphates. It is employed in medicine as an astringent, both internally and locally.

Ferric nitrate, $Fe_2(No_3)_6$, is formed, together with ferrous nitrate, by dissolving iron in nitric acid. The **liquor ferri nitratis** (U. S. P.), or **liquor ferri pernitratis** (Br.), is an aqueous solution of ferric nitrate, containing about 6.2 per cent. of $Fe_2(NO_3)_6$. Ferric nitrate crystallizes in rhombic prisms with $18H_2O$, or in cubes with $12H_2O$.

Scale Compounds of Iron.—These are certain salts of iron, mostly with organic acids, which do not crystallize readily, but are put into the market in the form of thin scales. They are prepared by evaporating their solutions to a thick, syrupy consistence, spreading upon glass plates, drying, and then detaching the thin scales from the glass. They are all used in medicine.

Ferri citras (U. S. P.)—citrate of iron—is prepared by dissolving freshly precipitated ferric hydroxide in a solution of citric acid, evaporating the solution to the proper consistency, and scaling. After its aqueous solution has been evaporated upon glass, it forms beautiful, thin, transparent scales, of a garnet-red color, slowly soluble in cold but freely in hot water, and possessing a mild, chalybeate taste.

Ferri et ammonii citras (U. S. P.). Citrate of iron and ammonia is formed by treating a solution of citrate of iron with ammonium hydroxide, and evaporating at a temperature that should not exceed 60° C. (140° F.).

It also forms garnet-red scales, which are readily and wholly soluble in water, forming a solution that is neutral to litmus paper and slightly styptic in taste.

Ferri et ammonii tartras (U. S. P.)—tartrate of iron and ammonia, a double salt—is formed by the action of tartaric acid upon ferric and ammonium hydroxides. Upon evaporating the solution, garnet-red scales remain, which are slowly soluble in water. Their solution is neutral to test-paper, and is of a sweetish, rather pleasant taste.

Ferri et potassii tartras (U. S. P.), **ferrum tartaratum** (Br.), **potassiotartrate of iron**, may be obtained by dissolving ferric hydroxide in a solution of acid tartrate of potassium and evaporating on glass. It forms ruby-red scales, having about the same properties as the ammoniotartrate.

Ferri et quiniæ citras (U. S. P., Br.)—citrate of iron and quinine—contains citric acid, ferric hydrate, and quinine citrate. It is pre-

pared by adding quinine and a little citric acid to a solution of ferric citrate, and evaporating. It forms transparent scales of a greenish tint, slowly soluble in cold water, but freely in hot water, forming bitter, slightly styptic solutions.

Ferri et strychninæ citras (U. S. P.) closely resembles the citrate of iron and ammonia in appearance, but has a bitter taste, and gives a white precipitate with ammonium hydroxide. It is prepared by adding a solution of strychnine citrate to a solution of citrate of iron and ammonium, evaporating on a water-bath to a syrup, and drying on glass.

Ferri Phosphas (Br.).—$Fe_2(PO_4)_2$. Phosphate of iron occurs as the result of a double decomposition between ferric sulphate and sodium phosphate. It forms a bright, slate-colored powder, insoluble in water, but soluble in acids.

Ferri phosphas solubilis (U. S. P.) is prepared by adding sodium phosphate to a solution of ferric citrate, evaporating down at a temperature not exceeding 60° C. (140° F.), and spreading upon glass to form scales.

Ferri Pyrophosphas Solubilis (U. S. P.).—$Fe_4(P_2O_7)_3$. Pyrophosphate of iron is formed by adding a solution of sodium pyrophosphate to a solution of a ferric citrate. It does not crystallize, but forms scales upon evaporating its solution. These are thin, apple-green in color, turn dark on exposure to the air, and are soluble in water, but not in alcohol. Ammonium hydroxide produces no precipitate in its solution, but sodium hydroxide does. The official salt contains forty-eight per cent. of anhydrous ferric pyrophosphate.

NICKEL.

Ni = 58.7.

Occurrence, Preparation, and Properties.—This metal is found native in meteorites. Its most common ores are **niccolite**, Ni_2AS_2, and **nickel glance**, $NiAs_2NiS_2$. These ores of nickel, however, usually also contain cobalt, and the cobaltous ores are also commonly nickel-bearing. The separation of nickel from its ores is a very complicated process, and for an account of it the reader is referred to works on metallurgy. Nickel may be prepared chemically pure by igniting its oxalate or carbonate in a stream of hydrogen. This metal is silver-white, tenacious, and very lustrous. Sp. gr., 8.9. It is attracted by the magnet. It does not alter in the air, but dissolves in the mineral acids, especially nitric.

Compounds.—The following are the most common of the nickel

compounds; they are mostly **ous** compounds, having the general form NiR_2, and all possess a green color : **nickelous hydroxide,** $Ni(OH)_2$; **nickelous chloride,** $NiCl_2.6H_2O$; **nickelous cyanide,** $Ni(CN)_2$; **nickelous sulphate,** $NiSO_4.7H_2O$; and **nickelous sulphide,** NiS. **Nickelic oxide,** Ni_2O_3, and **hydroxide,** $Ni_2(OH)_6$, exist, and are similar to the corresponding cobalt compounds. Nickel is used largely in certain alloys, and for electroplating.

COBALT.

$Co = 59.5$.

Occurrence, Preparation, Properties, etc. — Smaltite, $CoAs_2$, and **cobaltite,** $CoAs_2.CoS_2$, are the most commonly occurring native ores of cobalt. It is prepared in the same manner as nickel. It is a white metal, tenacious, and fusible with great difficulty ; sp. gr., 8.9. Its other properties are very similar to those of nickel.

Cobalt compounds are also chiefly **ous,** corresponding to the general form CoR_2. Those containing water have a reddish color ; the anhydrous compounds are blue.

The cobaltous compounds are : **cobaltous chloride,** $CoCl_2$; **cobaltous hydroxide,** $Co(HO)_2$; **cobaltous sulphate,** $CoSO_4.-7H_2O$; **cobaltous nitrate,** $Co(NO_3)_2.6H_2O$; and **cobaltous sulphide,** CoS.

The cobaltic compounds are **cobaltic oxide,** Co_2O_3, and **cobaltous-cobaltic oxide,** $Co_3O_4 = Co_2O_3.CoO$. The latter corresponds to magnetite, Fe_3O_4.

THE PLATINUM GROUP OF METALS.

The last six elements of **Group VIII** are usually classed as "metals of the platinum ores," or the **platinum group of metals.** The platinum ore, or crude alloy, occurs in small metallic grains in sands of a few regions, chiefly in the Ural Mountains, California, Brazil, Borneo, Australia, and Ceylon. These metals all form hydroxides (or salts representing them) having acid properties, and therefore play both the positive and negative rôles. Platinum is the only one used to any extent in the metallic condition. These metals are very heavy ; osmium has a sp. gr. of 21.47, the highest sp. gr. known.

PLATINUM.

Pt = 195.

Occurrence, Properties, etc.—It exists in nature associated with the other members of the group; also in ores containing gold, lead, silver, and iron.

It is a lustrous, white metal; sp. gr., 21.5. It is very tenacious, malleable, ductile, and is capable of being drawn out into very fine wire. At high temperatures it softens without melting; it fuses at about 1770° C. (3218° F.). Upon heating the double chloride of platinum and ammonium, it decomposes, leaving a grayish-black, spongy mass, called **platinum sponge.** This latter has the property of absorbing great quantities of certain gases. A jet of hydrogen projected upon it readily ignites, because of the condensation and oxidation of the hydrogen in the pores of the sponge, the heat developed being sufficient to ignite the hydrogen. Platinum is not affected by the air or oxygen. It unites with chlorine, arsenic, silicon, sulphur, and phosphorus. It does not dissolve in the single acids, and is only soluble in liquids generating free chlorine, as aqua regia. With many heavy metals it forms easily fusible alloys. Therefore, easily reducible metallic oxides, as those of arsenic, lead, etc., ought never to be ignited in platinum vessels. Platinum is valuable for its high fusing point and its power to withstand oxidation. It is expensive because of its scarcity.

Platinum Compounds.—These are of two series—platinous, PtR_2, and platinic, PtR_4. In the first the metal is more basic and in the latter more negative in nature.

Platinum tetrachloride, $PtCl_4$, is obtained by dissolving platinum in aqua regia and evaporating off the nitric acid. On evaporating, it crystallizes in soluble, reddish-yellow needles. With ammonium or potassium chloride and the alkaloids, it forms characteristic double chlorides. It is largely used as a reagent to precipitate potassium, ammonium, or the alkaloids, for quantitative estimation.

OSMIUM.

Os = 190.8.

This rare metal, occurring with some of the other platinum metals, is mentioned here for the sake of its oxide, OsO_4, which has received considerable attention as a staining agent. The metal resembles platinum.

The tetroxide, OsO_4 (so-called **osmic acid**), may be prepared by roasting the metal in air, or by the action of chlorine and moisture upon osmium. The oxide occurs as lustrous, transparent, yellow needles, having a very irritating, piercing odor, and is intensely poisonous. It has been used to arrest the motions or to kill the organisms in water, for microscopical examination.

Many kinds of organic substances reduce this oxide and precipitate the metal, and it is due to this property that it has found use as a staining agent in histology. It is used chiefly in a one per cent. aqueous solution for fixing and staining nerve-tissue. Fat is blackened by it.

Osmic acid has been employed as a remedy in neuralgia, goiter, scrofulous ulcers, and in epilepsy, in doses of $\frac{1}{50}$ of a grain.

PART IV.

ORGANIC CHEMISTRY.

Carbon and Hydrogen.—The substances derived from the ani- mal and vegetable kingdoms are composed principally of four ele- ments : carbon, hydrogen, oxygen, and nitrogen, with occasionally sulphur and phosphorus. Few as are the chemical elements con- cerned, the number of the compounds of these elements is almost endless. Formerly only those substances directly or indirectly derived from bodies possessing vegetable or animal life were considered as organic ; but as our knowledge increased, a large number of com- pounds were prepared in the laboratory from these bodies, which were identical with others prepared by plants and animals themselves. It was thus demonstrated that by pure chemical agencies many of the products of living organisms could be prepared, and that a vital prin- ciple was not necessary to form these compounds ; and also that by the same chemical action a great many compounds could be formed which could not be found in either animal or vegetable organisms. This greatly enlarged the field of investigation, and a new meaning was attached to the term **organic chemistry.** It was found neces- sary to extend the science to include all bodies in any way resembling organic compounds, either in composition or properties—*i. e.*, all compounds containing carbon and hydrogen. Carbon and hydrogen are the indispensable elements to the formation of organic bodies ; without these we can have no substance capable of vegetable or ani- mal life. In the great majority of organic compounds we also have oxygen or nitrogen, or both. The distinction between organic and inorganic compounds is more one of convenience than of absolute fact.

Organic chemistry may be defined as that branch of the science of chemistry which treats of the carbon compounds containing hydro- gen and of their derivatives.

While inorganic compounds, as a rule, contain but a few atoms, organic compounds frequently contain a large number ; and the diversity in organic chemistry is obtained not alone by varying the

kind of atoms, but by varying the arrangement of a few kinds. There exist, however, certain organized bodies which possess a structure entirely different from that of any known inorganic body or artificial organic substance. These *organized* structures are the sole product of vital action, and can not be produced in the laboratory. They are composed of a collection of organic substances of definite composition. Such composite bodies are the cells of living organisms; and although we may be able at some time to construct molecules identical with those composing them, we shall never be able to impart that function of growth, reproduction, and other vital processes which we call life. The complexity of organic compounds may readily be attributed to the inherent properties of the carbon atoms of which they are composed. The atoms of carbon exhibit, in a remarkable degree, a tendency to combine themselves into groups or chains, around which the other atoms or groups of atoms are arranged.

Qualitative Examination of Organic Bodies.—Organic bodies may usually be distinguished from inorganic by their behavior when heated. Organic bodies are either completely volatilized when moderately heated, or are decomposed into certain volatile products, leaving a black char behind them. When strongly heated in the air, they take fire and burn. Those which distil unchanged, deposit carbon when their vapor is conducted through a red-hot tube.

Carbon.—The best proof of the **presence of carbon** in an organic substance is given by burning it in an atmosphere of oxygen, or by heating it dry with CuO and collecting the CO_2 evolved. The presence of CO_2 may be shown by passing the gas from the combustion through a solution of lime-water. (See p. 216.)

The **quantitative estimation of carbon** is conducted on the same principle, but the CO_2 is absorbed by a solution of potassium hydroxide contained in a U-tube, and weighed before and after the experiment. The difference in these weights gives the weight of CO_2, from which the carbon may be calculated. This operation is conducted in a specially constructed furnace. The substance to be analyzed is mixed with oxide of copper in a hard-glass tube, which is then heated in the furnace shown in figure 60 by a row of gas-burners.

The watery vapor and CO_2 are passed through a previously weighed tube containing dry $CaCl_2$, which absorbs all the water. The CO_2 passes on and is absorbed by the solution of potassium hydroxide contained in the series of bulbs in the next tube, seen at the right of the furnace. When the combustion is complete, air is drawn through the apparatus, by the aspirator bottle shown at the right of the furnace. The air is first freed from moisture and CO_2, by passing through

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the train of jars shown at the left of the furnace. The increase in weight of the tube containing the $CaCl_2$ and that containing the KOH, gives the H_2O and CO_2 respectively, from which the hydrogen and carbon producing them may be calculated. The oxygen in organic compounds is always determined by the difference between the sum of the other elements found and the weight taken.

Nitrogen may be tested for by burning the substance in the air, when, if nitrogen be present in more than traces, it will give off an odor like that of burning feathers or horn. Some organic substances containing nitrogen, on being heated, explode. Another method of testing for nitrogen is to heat the substance with potassium hydroxide and lime in powder, when ammonia is evolved. This may be detected by its odor, its reaction with moistened litmus paper, or fuming HCl.
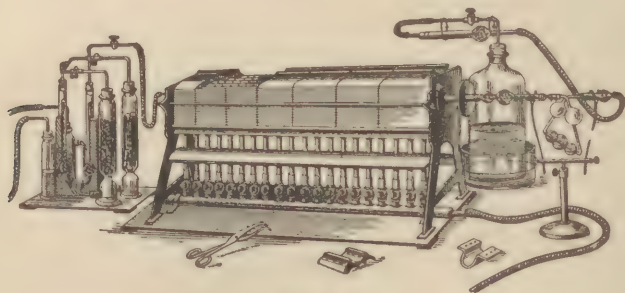
FIG. 60.

Sulphur may be detected in many cases by heating the substance with a strong solution of potassium hydroxide and adding a solution of a lead salt, which is turned black on heating if sulphur be present. Another method of testing for sulphur: **Solids** are fused with two parts of potassium hydroxide and one of potassium nitrate. After cooling, the mass is dissolved in water, HCl added, and sulphates tested for with $BaCl_2$. **Liquids** are treated with fuming HNO_3, or a mixture of HNO_3 and $KClO_3$, with a gentle application of heat. The solution may then be tested for sulphates as above. (See p. 165.)

The **halogens** may be detected by heating the substance with lime, afterward dissolving in water, acidifying with HNO_3, and adding a solution of $Ag(NO_3)$. The halogens are precipitated either as AgCl, AgBr, or AgI.

Phosphorus may be detected by fusing the substance with KNO_3 and KOH, dissolving in water, and testing for phosphoric acid.

THE PHYSICAL PROPERTIES OF ORGANIC COMPOUNDS.

The physical examination of an organic compound includes the determination of its solubility in various menstrua, the fusing point, the boiling point, the vapor density, the freezing point and osmotic pressue of its solutions if non-volatile, its crystalline form, and its optical behavior in the polariscope.

Fusing Point.—When pure, the fusing point of organic compounds is fairly constant. Some of these compounds, however, decompose before reaching their fusing points.

The fusing point is usually determined by placing a small quantity of the substance in a capillary tube, made by drawing off a piece of glass tubing after heating it in the flame of a Bunsen burner. This tube is now fastened to the side of a thermometer by a rubber band, so that the substance is opposite the bulb of the thermometer. The thermometer and capillary tube are then placed in a bath of water or paraffin, contained in a beaker or flask, and the bath is gradually heated. When the substance melts, the temperature of the bath is noted.

Boiling Point.—Most organic liquids boil at a constant temperature, and without decomposition. A mixture of different liquids does not have a constant, but a variable boiling point. The boiling point at a constant atmospheric pressure is one of the most important means of determining the purity and the identity of an organic compound. The boiling points of organic liquids serve to separate one from another having a higher or lower boiling point, by the process known as fractional distillation. In this process the mixed liquids are placed in a retort or distilling flask, with a thermometer suspended above the liquid; heat is now applied to the retort, and the distillates coming over at fixed intervals of temperature are collected separately. By repeating the process the liquids may finally be separated. The boiling point of a liquid is determined by placing it in a distilling flask or retort, and suspending a thermometer through a perforated cork in the neck of the flask so that the bulb is just above the surface of the liquid. That is, we determine the temperature of the escaping vapor.

Vapor Density.—The vapor density of volatile organic compounds affords an easy and certain means of determining their molecular weights. On page 89 we have seen that the molecular weight of any body is twice its density in the gaseous state, or the density of a gas or vapor is half its molecular weight. The easiest method of

determining the vapor density of a substance is that known as Victor Meyer's.

The apparatus (represented by Fig. 61) consists of an outer tube of glass (a), the bulb of which contains water or other fluid which has a constant and known boiling point. The inner tube (b) con-

tains air, is stoppered at the upper end, and is provided with a delivery tube (d) to allow the escape of the air, as it is heated by the vapor of the boiling fluid in the outer tube.

The open end of this tube is placed in a cup, under water, while the water is being boiled. As soon as the air ceases to escape from the delivery tube, the cork (e) is removed from the top of the inner tube (b), and a small vial containing a weighed amount of the liquid to be examined is dropped in, and the cork quickly inserted. The heat boils the liquid, forces out the stopper in the vial, and the vapor thus produced drives out an equal volume of air through the delivery tube.

This air is collected in the graduated tube (f) previously placed over the open end of the delivery tube and carefully measured.

The volume of air obtained represents the volume of the vapor, at the temperature of boiling water or of the liquid used in the outer tube. The true volume under standard conditions is now to be calculated by the formula given on page 27. Practically, this correction is usually made by reference to tables prepared for the purpose.

The volume of the vapor of a liquid of known weight having been determined, we may easily calculate the density.

For example, suppose 0.1 gm. of alcohol be taken, and we obtain 48 5 c.c. of air after making the necessary corrections. Now, 0.1 gm. of hydrogen measures 1116 c.c. at 0° C. and 760 mm. pressure. We now compare these volumes, and we
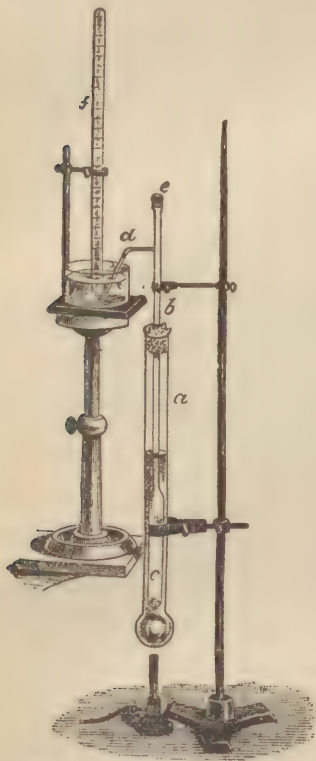
have $\dfrac{1116}{48.5}$. 23, or the hydrogen occupies 23 times the volume of an equal weight of alcohol vapor.   Or, one liter of hydrogen under standard conditions weighs 0.0899 gm., a crith. (p. 116).   One c.c. of hydrogen then weighs 0.0000899 gm. ; 48.5 c.c. of hydrogen will weigh 0.00436 gm.   By dividing the weight of the alcohol taken, 0.1 gm., by the weight of 48.5 c.c. of hydrogen, we obtain 23 as the density of the alcohol vapor.   As the density of the alcohol vapor is 23, its molecular weight must be 46 (p. 89).

Determination of Molecular Weight by Freezing Point of Solutions.—The effect of dissolved substances in lowering the freezing point of the solvent was first discovered by Blagden in 1788, who stated that the depression of the freezing point of aqueous solutions is proportional to the strength of the solution.   Raoult has developed this law into the following : *Solutions containing, in equal volumes of a solvent, quantities of dissolved substances proportional to their molecular weights have the same freezing point.*   The relation between the solid in a solution and its solidifying point furnishes a means of determining the molecular weight of soluble non-volatile substances.   This method consists in determining the amount of the lowering of the freezing point of a solvent, due to the substance dissolved in it.   The lowering of the freezing point is proportional to the quantity of the solid in solution.   While this law is not perfectly uniform for inorganic substances, it is, with a very few exceptions, uniformly so with organic substances.   Let 1 gm. of a compound be dissolved in 100 gm. of a liquid with which it forms no chemical union.   Let the molecular weight of this compound be represented by M.   If we now cause the solution to freeze, we shall observe that it freezes at a lower temperature than the solvent.   This depression of the freezing point we will represent by D.   If we multiply this depression by M, the molecular weight of the compound, we shall have the depression for M gm. of the substance—*i. e.*, the molecular weight expressed in grams.   Let this be represented by T.   Then we shall have $D \times M = T$.   Raoult found that the value of T is very nearly constant for the same solvent.   The value of T for water is 19, for acetic acid 39, for benzene 49.   Now, as D is determined by experiment, and T is constant, M may be easily calculated by dividing T by D, or $M = \dfrac{T}{D}$.   For example, a solution of glucose containing 10 gm. to 100 gm. of water was placed in a beaker of 400 c.c. capacity, and provided with a three-holed cork—one hole for the thermometer, one for the stirring rod.   It was cooled to —2° C.   A crystal of ice from a similar solution was dropped in, through the third hole in the cork, to make it freeze.   The thermometer rose to —1.06° C.   The depression due to 1 gm. was then one-tenth of this, or 0.106° C.   Hence,

19 ÷ 0.106 = 179 as the molecular weight of glucose. Analysis gives us the empirical formula, $CH_2O = 30$. By multiplying this number by 6 the result is 180, which is near enough to determine that as its formula, instead of any other multiple of 30. The slight difference here is within the limits of experimental error.

To deduce the formula from analysis. Rule: Divide the percentage of each element by its atomic weight, and express the ratio of these quotients in their lowest terms.

Analysis of Alcohol.

C = 52.16.
O = 34.80.
H = 13.04.
52.16 ÷ 12 = 4.34 atoms of carbon.
34.80 ÷ 16 = 2.17 atoms of oxygen.
13.04 ÷ 1 = 13.04 atoms of hydrogen.
Ratios: C, 4.34; O, 2.17; H, 13.07.
Lowest terms: C, 2; O, 1; H, 6.

As per cent. is equivalent to parts in one hundred, we may calculate the amount of carbon in each molecule by the following proportion: 100 : 46 : : 52.16 : 23.99; or in 46 parts of alcohol there are approximately 24 parts of carbon.

For oxygen we have 100 : 46 : : 34.80 : x = 16.008.

For hydrogen we have 100 : 46 : : 13.04 : x = 5.998. The atomic weight of carbon is known to be 12, or each molecule contains 2 atoms of carbon. As the atomic weight of oxygen is 16, each molecule contains 1 atom of oxygen. As the atomic weight of hydrogen is 1, each molecule of alcohol contains 6 atoms of hydrogen.

The molecular formula of alcohol is C_2H_6O, making the molecular weight 46. The vapor density of alcohol we found above to be 23; its molecular weight, therefore, is 46.

Hydrocarbons.—The simplest organic compounds are the hydrocarbons, consisting of carbon and hydrogen only. Carbon being a tetrad, can combine with four atoms of hydrogen, thus: $H—\overset{H}{\underset{H}{\overset{|}{C}}}—H$.

It also shows a marked tendency to unite **with other carbon atoms** to form groups of carbon atoms more or less characteristic and stable.

One atom of carbon may thus unite with another carbon atom, and the two atoms thus united will combine with six monad or hydrogen atoms: $\overset{H}{\underset{H}{>}}C—C\overset{H}{\underset{H}{<}}H$. Three, four, five, or any number (n) atoms of

carbon may thus unite, theoretically at least, and give rise to a chain of atoms which has been called an **open chain**. Or the carbon atoms may
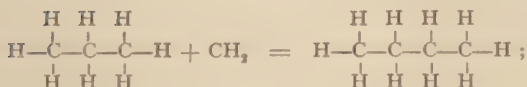
combine as follows : (structural ring formulae) or (structural ring formula) , giving rise to
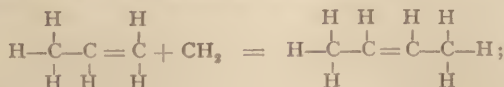
closed chains, or **cycles**.

By a little consideration, it will be seen that, in either of the first two formulæ given above, if we increase the carbon atoms in any given formula, we also increase the number of **bonds**, or points of contact for hydrogen atoms, by two for every carbon atom added. Thus :

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H;$$

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H;$$

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H;$$

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H;$$
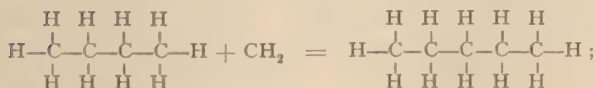
and so on.

We thus have a series of hydrocarbons differing from each other by the constant quantity of CH_2. Such a series is called a **homologous series**. In the same chain of carbon atoms we might have the following arrangement of the bonds of attraction :

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{C}=\overset{\overset{H}{|}}{C} + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{H}{|}}{C}=\overset{\overset{H}{|}}{C}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H;$$

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{H}{|}}{C}=\overset{\overset{H}{|}}{C}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H + CH_2 = H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\overset{\overset{H}{|}}{C}=\overset{\overset{H}{|}}{C}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H.$$

This gives rise to another homologous series, each member differing from the corresponding member of the series above mentioned by the constant quantity of H_2. A series of hydrocarbons differing by H_2 are known as an **isologous series**. In the vertical columns of the following table we have the **homologous series**; in reading from left to right we have the **isologous series** of hydrocarbons.

CH_4	CH_2*	$C*$	
C_2H_6	C_2H_4	C_2H_2	
C_3H_8	C_3H_6	C_3H_4	C_3H_2
C_4H_{10}	C_4H_8	C_4H_6	C_4H_4
C_5H_{12}	C_5H_{10}	C_5H_8	C_5H_6
C_6H_{14}	C_6H_{12}	C_6H_{10}	C_6H_8
C_7H_{16}	C_7H_{14}	C_7H_{12}	C_7H_{10}
C_8H_{18}			
C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	C_nH_{2n-4}

In the general formulæ (n) may represent any number of carbon atoms, and is intended simply to express the relation between the number of C and H atoms.

This table does not by any means represent all the possible compounds, but gives an idea of how all known hydrocarbons may be classified, by extending the table.

The members of these series having but a few carbon atoms in their molecules are termed the **lower** members, and those having a higher number of carbon atoms the **higher** members.

Isomerism.—Besides the method of grouping the carbon nuclei which we have indicated, a variety of other methods may be conceived, some of which really exist. Thus, the group containing four carbon atoms may be arranged as follows:
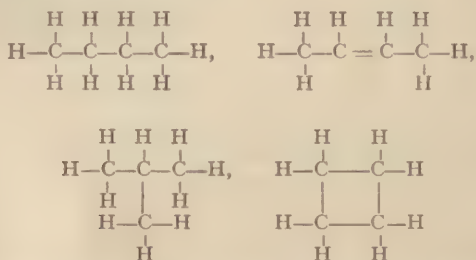
The first and third of these would have the same number of atoms and the same empirical formula, C_4H_{10}, but would have different physi-

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* Unknown.

cal and chemical properties. Compounds having the same chemical composition, but possessing different properties, are termed **isomeric bodies**. The chemical and physical properties of organic compounds depend not only upon the kind and number of atoms, which is designated the **composition** of the molecule, but also upon the arrangement of the atoms in the molecule, or the **constitution**.* The second and fourth of the above formulæ are quite different in the *constitution*, while they are the same in *composition*. These two compounds are isomeric. It is in this way that we may have several compounds, each answering to the same formula, and giving the same result on analysis, but totally different in properties. We may mention here, as examples, ammonium cyanate, NH_4OCN, and urea, $CO \begin{cases} NH_2 \\ NH_2. \end{cases}$ Also:

$$N \begin{cases} C_3H_7 \\ H \\ H \end{cases} \qquad N \begin{cases} CH_3 \\ C_2H_5 \\ H \end{cases} \qquad N \begin{cases} CH_3 \\ CH_3 \\ CH_3 \end{cases}$$

Propylamin. Methyl-ethylamin. Trimethylamin.
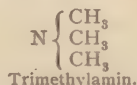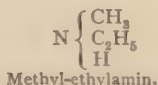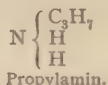
This phenomenon of bodies of the same class having the same composition and different constitution and physical or chemical properties is called **isomerism**.†

In those members of the above series of hydrocarbons having four or more carbon atoms, we may have several isomers. The number of these isomers increases rapidly with the increase of the carbon atoms. Thus, there are two possible butanes, known as butane and iso-butane, or methyl-propane.

Butane.

Methyl-propane
or
Iso-butane.
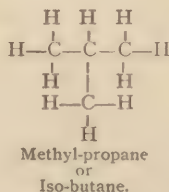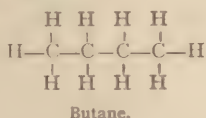
The number of possible isomers increases rapidly with the number of carbon atoms in the molecule. There are two isomers for C_4H_{10}; for C_5H_{12}, three isomers; for C_6H_{14}, five; for $C_{10}H_{22}$, seventy-five; and for $C_{11}H_{24}$ it has been computed that we may have no less than 159 isomers. This fact explains why we can have an indefinite number of compounds classified in the above table. This same law of isomers applies to the other homologous series as well as to the first.

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* See definition of empirical and structural formulæ, page 94.
† Metamerism is sometimes used as synonymous with isomerism.

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Polymeric bodies are compounds having the same percentage composition but different molecular weights. As the name indicates, the one is a multiple of the other. It is usually applied only to substances of the same class of compounds. We have a striking example of this property in the second column of the table on page 312. Ethene, C_2H_4, butene, C_4H_8, and octene, C_8H_{16}, are polymeric bodies. Starch, cellulose, dextrin, and glycogen are probably polymeric bodies, and familiar illustrations of the phenomenon of **polymerism.**

Nomenclature of Organic Compounds.—The nomenclature of organic compounds is complicated and unsatisfactory. The large number of compounds, and their endless derivatives to be considered, make it next to impossible to devise a system of naming them that shall meet with general approval. The result of the rapid advance in the discovery of organic compounds has been to produce confusion in this respect.

Certain compounds have received different names from different observers, and it is no unusual thing to meet with four or five synonymous names for the same compound. In consequence of this, a Commission, appointed by an International Congress of Chemists which met at Paris in 1889, attempted to revise the whole subject of nomenclature.

The Commission has published, as the result of its deliberations, a preliminary report embracing sixty-two rules for naming organic compounds. These rules are, as yet, not generally adopted. It may be stated, however, that the nomenclature of organic compounds is in the transitional stage. We shall endeavor to follow the best usage in the naming of chemical compounds.

Organic Radicals.—In organic chemistry, as in inorganic, although to a greater extent, we are constantly dealing with certain well-defined groups of atoms, which retain their identity through a large series of compounds, and behave in chemical reactions like simple radicals or atoms.

It is evident that by removing one or more atoms of hydrogen from any saturated hydrocarbon, the remaining group of atoms may act as a compound radical ; while the unsaturated hydrocarbons of the second or third series may act as radicals without the removal of any hydrogen atoms.

These hydrocarbon radicals are usually designated by the termination **yl.** Thus: CH_3 is known as methyl ; C_2H_5, as ethyl ; C_6H_5, as phenyl. These radicals are called, collectively, **hydrocarbon, alcohol,** or **alkyl radicals,** and the quality of their combining power is electropositive.

The following radicals are frequently met with in organic compounds, and ought to be committed to memory by the student:

Hydroxyl (OH), ... occurring in alcohols.
Carbonyl (CO), ... " " ketones.
Carboxyl (COOH), ... " " organ c acids.
Cyanogen (CN), ... " " cyanides.
Nitroxyl (NO_2), ... " " nitro- compounds.
Nitrosyl (NO), ... " " nitrosyl compounds.
Sulphonyl (SO_2OH), ... " " sulphonic acids.
Amidogen (NH_2), ... " " amids.
Methyl (CH_3), ... " " wood-alcohol.
Ethyl (C_2H_5), ... " " alcohol.
Amyl (C_5H_{11}), ... " " fusel oil.
Phenyl (C_6H_5). . . . . " " carbolic acid.
Acetyl (C_2H_3O), ... " " acetic acid.
Benzoyl (C_7H_5O), ... " " benzoic acid.

All organic bodies can be classified in one or other of the following groups: **Hydrocarbons, alcohols, ethers, aldehydes, acids, acetals, ketones, halogen compounds, ethereal salts, amins, amids, nitrils, cyanogen compounds, quinons, organo-metallic compounds, carbohydrates, proteids, alkaloids, and glucosides.**

HYDROCARBONS.

The first and simplest class of organic compounds we shall meet are the hydrocarbons.

Nomenclature.—The following are the names proposed for these hydrocarbons:

1st Series. PARAFFINS.	*2d Series.* OLEFINS.	*3d Series.* ACETYLENES.	*4th Series.*	*5th Series.*
C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	C_nH_{2n-4}	C_nH_{2n-6}
Methane, CH_4.	Methene (unknown), CH_2.	Carbon, C.		
Ethane, C_2H_6.	Ethene, C_2H_4.	Ethine (Acetylene), C_2H_2.		
Propane, C_3H_8.	Propene, C_3H_6.	Propine, C_3H_4.	Propone, C_3H_2.	
				Quartune, or Butune. C_4H_2.
Butane, C_4H_{10}.	Butene, C_4H_8.	Butine, C_4H_6.	Butone, C_4H_4.	
Pentane, C_5H_{12}.	Pentene, C_5H_{10}.	Pentine, C_5H_8.	Pentone, C_5H_6.	Pentune, C_5H_4.
Hexane, C_6H_{14}.	Hexene, C_6H_{12}.	Hexine, C_6H_{10}.	Hexone, C_6H_8.	Hexune, C_6H_6.

Here, as above stated, there is not perfect uniformity in nomenclature, and where they conflict we shall follow the best usage, in preference to strict conformity to the above.

The Paraffins.—The paraffins (from *parum*, too little, and *affinis*, affinity) are chemically indifferent bodies, because they are fully saturated compounds. They are stable and not easily attacked by reagents. They are not acted upon by alkalies or acids. Many of these hydrocarbons are found in petroleum and the gases accompanying it, and some are found in the products of the dry distillation of coal and other organic substances. They may also be prepared by one of the following reactions :

1. By treating an alkyl iodide with zinc in a closed tube at 160° C. (320° F.) in presence of water.

$$C_2H_5I + HOH + Zn = C_2H_6 + Zn \left\{ {OH \atop I} \right.$$
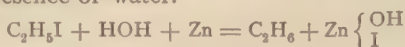
2. By heating certain salts of the acids containing one or more carbon atoms with an alkali. Thus, by heating calcium acetate with sodium hydroxide :

$$(C_2H_3O_2)_2Ca + 2NaOH = 2CH_4 + Na_2CO_3 + CaCO_3.$$

3. By electrolysis of the acids of the acetic acid series.

The lower paraffins are gaseous and are insoluble in water. Those below butane are gases at ordinary temperatures, those between C_4H_{10} and $C_{16}H_{34}$ are liquids, and the higher members are solids. Alcohol dissolves the gases slightly, the liquids readily, and the solids with difficulty. The boiling point, the melting point, and the specific gravity increase with the increase of carbon atoms.

Methane, or Marsh-gas.—CH_4. This gas is a constant product of the decomposition of vegetable matter under water, and may frequently be seen rising to the surface of stagnant pools. It is produced by the dry distillation of coal, and is therefore a constituent of ordinary illuminating gas. It is the chief constituent of miners' "fire-damp." It occurs in the gases of the intestines to the extent of from twenty-five to fifty per cent.

Natural gas is composed of from ninety to ninety-five per cent. of marsh-gas, with small quantities of nitrogen and carbon dioxide.

Preparation.—Methane may be prepared by heating a mixture of 4 parts of sodium acetate, 4 parts of sodium hydroxide, and 6 parts of lime. It may be prepared synthetically by the following reactions : The electric arc in an atmosphere of hydrogen produces a small quantity of ethine. Ethine may also be produced by the reaction between calcium carbide and water. (See Calcium Carbide.)

$$C_2Ca + H_2O = C_2H_2 + CaO.$$

Ethine, when mixed with hydrogen and passed through a tube containing spongy platinum, forms ethane, C_2H_6.

$$C_2H_2 + 2H_2 = C_2H_6.$$

Ethane passed through a heated tube gives the following reaction:

$$2C_2H_6 = 2CH_4 + C_2 + 2H_2.$$
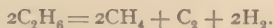
When a series of electric sparks are passed through a mixture of hydrogen and carbon monoxide, CH_4 is prepared.

$$CO + 3H_2 = CH_4 + H_2O.$$
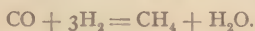
By these reactions the elements are made to yield CH_4 and C_2H_6, which can serve as the starting point in the synthesis of other organic compounds, and thus bridge over the gap between inorganic and organic compounds.

Properties.—Methane is a light, colorless, transparent, odorless, tasteless, combustible gas. Density = 8. Sp. gr. = 0.559. Under 140 atmospheres of pressure at 0° C. (32° F.), it condenses to a transparent liquid. It burns in the air with a bluish flame, giving no light, but a high temperature. Mixed with air or oxygen, it forms an explosive mixture (" fire-damp "). By passing the gas through a red-hot tube it is converted into carbon and hydrogen, with traces of C_2H_2, C_2H_4, C_2H_6, and $C_{10}H_8$. Mixed with Cl and diluted with CO_2, it forms chlorine substitution compounds, CH_3Cl, CH_2Cl_2, $CHCl_3$, and CCl_4.

It is irrespirable, but not poisonous. Poisoning by house-gas containing CH_4 is produced by the other gases which it contains.

Ethane, or **dimethyl,** $CH_3—CH_3$, occurs in crude petroleum, and is a constituent of some of the natural-gas wells of western Pennsylvania. These gas wells discharge large volumes of gas, containing H, CH_4, and C_2H_6, which is used for heating and lighting in the neighboring districts. When crude petroleum is heated, the hydrocarbons ethane, propane, and butane are evolved as gases. These are collected and subjected to condensation, yielding a liquid consisting chiefly of butane, C_4H_{10}, known as cymogene, which is used in ice machines.

Properties.—Ethane is a gas at ordinary temperatures, but is condensed to a liquid at a pressure of forty-six atmospheres at 4° C. It burns with a faintly luminous flame. It is slightly soluble in water and alcohol.

Propane, C_3H_8, is present in crude petroleum, and is a liquid below —30° C. (—22° F.). It may be prepared artificially by the action of hydriodic acid, HI, upon glycerin at 275° C. (527° F.).

Butane, C_4H_{10}, boils at 1° C. (33.8° F.). Its sp. gr. is 0.6, being the lightest liquid hydrocarbon known. It is found in crude petroleum.

There are two isomeric butanes, having the following structural or graphic formulæ :

$$H—\overset{\overset{\displaystyle H}{|}}{C}—\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}—\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}—\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}—H \qquad \text{and}$$
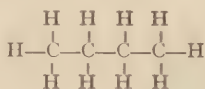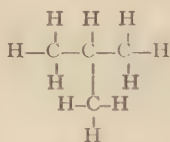
Butane.

Iso-butane.

Iso-butane boils at —17° C. (1.4° F.).

The **normal paraffins** are regularly formed compounds, in which no C atom is linked to more than two other C atoms.

In the **isoparaffins** one carbon atom is linked to three others, as in iso-butane above.

In the **neoparaffins** two carbon atoms are each linked to three others.

$$H_3C—\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle CH_3}{/}}{C}}—\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}—CH_3$$
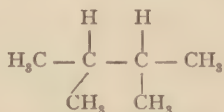
That is, in the iso- compounds we have one side-chain ; in the neo-compounds we have two side-chains.

In the **mesoparaffins** one carbon atom is linked to four others.

$$H_3C—\overset{\overset{\displaystyle CH_3}{|}}{\underset{\underset{\underset{\underset{\displaystyle CH_3}{|}}{CH_2}}{|}}{C}}—CH_3$$
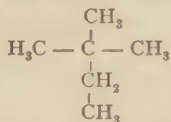
The higher members of this series are found in American petroleum, and may be isolated to a great extent by careful fractional distillation.

PETROLEUM.

Petroleum is a natural, oily, dark-brown liquid issuing from the earth, or pumped from wells in various parts of the globe. It is believed to be derived from the subterraneous distillation of vegetable and, possibly, animal matter. The chief localities where it is obtained are Pennsylvania, western New York, and Canada ; Baku, on the shores of the Caspian Sea ; Hanover, Alsace, and Galicia. Burmah, India, and Japan also have produced some petroleum.

The distillation of petroleum is carried on on a large scale in certain parts of this country, and a variety of products are found in

the market, the names of which have no reference to the chemical composition. The following are a few of the most important of these products, with their boiling points and uses:

NAME.	BOILING POINT.	PRINCIPAL USE IN ARTS.
Cymogene, ...	0° C. (32° F.)	Used in ice machines.
Rhigolene, ...	18.3° C. (65° F.)	Used to produce cold by evaporation and as an anesthetic.
Petroleum Ether, . . .	40° to 70° C.(104° to 158° F.)	As a solvent and for making "air-gas."
Gasolene, ...	48.8° C. (120° F.)	For making "air-gas."
C-Naphtha, ...	82.2° C. (180° F.)	As a solvent for fats and rubber;
B Naphtha, ...	104.4° C. (220° F.)	hence for cleaning clothes.
A-Naphtha, ...	148.8° C. (300° F.)	So-called "safety-oil."
Benzine (deodorized), .	120° to 150° C. (248° to 302° F.)	For varnishes and paints.
Kerosene, or Refined Petroleum, ...	176° C. (349° F.)	For ordinary lamps.
Mineral Sperm Oil, . .	218° C. (424° F.)	
Lubricating Oil, . . .	301° C. (574° F.)	Lubricating machinery.
Paraffin, ...	Solid. Melts at 45° C. to 65° C. (113° F. to 149° F.)	For candles.

The vapors of all the lighter products, when combined with air, form explosive mixtures, and hence laws exist in most countries prescribing the lowest temperature at which kerosene shall give off an inflammable vapor, or at which it shall "flash." The law of the State of New York declares that oils used for illuminating purposes shall not give a vapor that will "flash" below 100° F., and shall not themselves ignite below a temperature of 300° F. Commercial oils are mostly brought to a fire test of either 110° F., 120° F., or 150° F.

Kerosene, coal-oil, or **illuminating oil** is prepared from that portion of petroleum distilling over between 150° C. and 220° C. (302° F. to 425° F.). The distillate is "refined" by treatment in a large tank with a two per cent. solution of sulphuric acid, to remove the unsaturated hydrocarbons, which, if left in, would gradually oxidize and turn dark. The remaining liquid is then treated with a weak solution of NaOH to remove the H_2SO_4, and then redistilled.

Benzine, benzinum (U. S. P), is a purified distillate from American petroleum consisting of a mixture of hydrocarbons, chiefly of the marsh-gas series, C_5H_{12}, C_6H_{14}, and homologues. It is a colorless, transparent, mobile liquid, of aromatic odor.

It has a sp. gr. of 0.670 to 0.675, and boils at from 50° C. to 60° C. (122° F. to 140° F.). It is used principally as a solvent for fats, resins, alkaloids, and rubber. Owing to its solvent power for fats, it is used as a household article for cleaning fabrics.

Commercial benzine is usually heavier than the above liquid and has a higher boiling point.

Petrolatum liquidum (U. S. P.) is a colorless or yellowish, transparent, odorless, tasteless, oily liquid, giving off when heated a faint odor of petroleum. It consists chiefly of hydrocarbons of the marsh-gas series, and is obtained from petroleum by distilling off the more volatile portions and purifying that portion of the distillate having the proper consistence. Specific gravity, about 0.875 to 0.945 at 15° C. (59° F.). It is insoluble in water, but soluble in hot absolute alcohol, in ether, chloroform, benzine, carbon disulphide, turpentine, and the fixed and volatile oils.

Albolene, benzoinol, and **liquid vaseline** are trade names for similar liquids.

Vaseline.—Petrolatum molle (U. S. P.) and **petrolatum spissum** (U. S. P.) are described as mixtures of hydrocarbons, chiefly of the marsh-gas series, obtained by distilling off the lighter and more volatile portions from petroleum, and purifying the residue when it has the desired melting point. The first has a melting point of 40° C. to 45° C. (104° F. to 113° F.), and the second of 45° C. to 51° C. (113° F. to 125° F.). They are fat-like masses having a white to deep yellow color, and more or less fluorescent.

Paraffin, Paraffinum Durum (Br.).—This is a white, wax-like solid, prepared by distillation from bituminous shales, or from the residue of the distillation of petroleum or bitumen. It is also prepared from ozokerite. Its hardness and melting point vary with its source. Its melting point varies from 51.6° C. to 62° C. (125° F. to 143.6° F.). It is a mixture of saturated hydrocarbons, and is soluble in ether, benzene, and all the lighter hydrocarbon oils, the ethereal and fatty oils, carbon disulphide, and but slightly soluble in alcohol. When melted with wax, spermaceti, or stearin, it mixes with them in all proportions. It is used chiefly for making candles, for finishing calicoes, for making translucent waterproof paper, and chewing gum. It is employed in pharmacy as a coating for pills, glycerin suppositories, etc.

Ozokerite, or **mineral wax,** is a wax-like solid, consisting of paraffin mixed with lighter oils. It is used for the manufacture of lubricating oils and paraffin. It is often used to prepare **ceresin,** a substance resembling wax, and used as a substitute for it.

The Olefins, or C_nH_{2n} **Series.**—The olefins differ from the paraffins in being unsaturated compounds. The first member of the series, ethene or ethylene, C_2H_4, combines directly with chlorine, forming a thick, oily fluid, from which the discoverers named it olefiant gas. The iodide and bromide may also be formed by direct

union. The olefins combine with the hydracids, HCl, HBr, HI, and also with fuming H_2SO_4, and with HNO_3.

$$C_2H_4 + HCl = C_2H_5Cl.$$

Most olefins are soluble in alcohol and ether, but most of them are insoluble in water. They are soluble in strong H_2SO_4. **Ethene** is found in illuminating gas, the illuminating power of which depends largely upon its presence. It is a colorless gas of a peculiar, pungent odor, and may be separated from the other constituents by its solubility in H_2SO_4, with which it combines. It burns in the air with a bright, luminous flame. Its sp. gr. is 0.9785; density, 14. The higher members of this group are unimportant. The following are the chief members of the series:

Ethene, C_2H_4, gas.	Heptene, C_7H_{14}, boils at 100° C.
Propene, C_3H_6, gas.	Octene, C_8H_{16}, boils at 125° C.
Butene, C_4H_8, gas.	Nonene, C_9H_{18}, boils at 153° C.
Pentene, C_5H_{10}, boils at 35° C.	Decene, $C_{10}H_{20}$, boils at 200° C.
Hexene, C_6H_{12}, boils at 70° C.	

Third Series.—Ethine, or acetylene, C_2H_2.—This series of hydrocarbons falls short of saturation by four monad atoms, and can, therefore, act as bivalent and tetrivalent radicals. The first member of the series, ethine, C_2H_2, is the only hydrocarbon which can be formed by the direct union of its elements. It is produced when carbon is strongly heated in an atmosphere of hydrogen; that is, by passing a powerful electrical current between carbon poles in a globe filled with hydrogen. It may be prepared in quantity by the reaction between calcium carbide and water.

$$CaC_2 + H_2O = CaO + C_2H_2.$$

It has been proposed to prepare the gas by this method as a substitute for ordinary illuminating gas. The cost of production has thus far prevented its general adoption. One gram of CaC_2 is sufficient to yield 200 c.c. of the gas. Ethine, or acetylene, combines directly with either two or four atoms of chlorine, bromine, or iodine. Nascent hydrogen converts it into ethene, and oxidizing agents (potassium permanganate, etc.) into oxalic acid.

$$5C_2H_2 + 4K_2Mn_2O_8 + 12H_2SO_4 = 4K_2SO_4 + 8MnSO_4 + 5H_2C_2O_4 + 12H_2O.$$
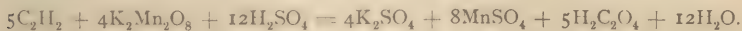
It is found in coal-gas, and possesses a high illuminating power. This hydrocarbon is remarkable for the fact that its hydrogen is easily displaced by metals; thus, by heating sodium with C_2H_2 we obtain C_2HNa (**monosodium acetylid**) and C_2Na_2 (**disodium acety-**

lid). When passed into a solution of silver nitrate it forms a white precipitate of **silver acetylid,** $C_2Ag_2H_2O$, an explosive compound.

Fourth Series.—General formula, C_nH_{2n}—$_4$. This series of hydrocarbons includes turpentine and a large number of other so-called essential or volatile oils. To this series belong the **terpenes,** a class of hydrocarbons more or less resembling the turpentines in physical properties. Some of them show a close relationship to the aromatic hydrocarbons. The terpenes are isomers or polymers having the formula $(C_5H_8)_n$. These hydrocarbons are unsaturated, and those of the formula $C_{10}H_{16}$ may combine with either one or two molecules of the haloid hydracids HCl, HBr, HI, or with two or four atoms of bromine, showing that their molecules contain either one or two double-linked carbon atoms.

Many of the terpenes form characteristic compounds with nitrous acid, called nitrosites, $C_{10}H_{16}N_2O_3$; and also with nitrosyl chloride, NOCl, called nitroso-chlorides. These compounds are crystalline. Some of these compounds form crystalline hydrates with water, especially in the presence of dilute nitric acid and alcohol, such as terpin hydrate. Some of them polymerize when heated under pressure, or when shaken with strong H_2SO_4. Many of them are optically active, and all have an antiseptic action.

Turpentine, terebinthina (U. S. P., Br.), **pinene,** is an oleoresin exuding from several varieties of the conifera family, notably the pines. It is a yellow, opaque, tough mass, brittle when cold, and having a terebinthinate odor and taste. When turpentine is distilled, the terpenes volatilize, forming **oil of turpentine, or spirits of turpentine,** while **rosin,** or **colophony,** remains in the still. Oil of turpentine is a mobile, colorless liquid, with a sp. gr. of 0.855 to 0.870, and boils at 160° C. (320° F.). It is almost insoluble in water, but dissolves in alcohol, ether, and glacial acetic acid. It dissolves sulphur, resins, and phosphorus. It absorbs oxygen from the air and becomes oxidized, forming a resinous body. The absorbed oxygen is converted into ozone, and this explains its oxidizing, disinfectant, and antiseptic action. As the oxidation of turpentine takes place more rapidly when mixed with lead oxide, this oxide is often intermixed with the turpentine in paints, to increase the rapidity of drying. It attacks lead rapidly, but not tin.

A paper dipped in turpentine and introduced into a jar of chlorine gas inflames spontaneously, forming substitution products. Iodine and bromine have a similar action upon it. It unites directly with HCl, producing several chlorides.

Sulphuric acid acts violently upon turpentine, and yields a number of isomeric and polymeric derivatives. After standing twenty-four

hours, the mixture separates into two layers. The upper layer, when distilled at about 250° C. (482° F.), yields a mobile liquid, which, when purified by longer contact with H_2SO_4, and then with a solution of NaOH, and redistilled, may be separated into **terebene**, $C_{10}H_{16}$, **colophene**, and several other polymers. These compounds are used in medicine.

Terebene, terebenum (U. S. P.), has a fine, thyme-like odor, and is optically inactive. In density and other respects it much resembles turpentine. It is a liquid consisting chiefly of pinene, with small quantities of terpinene and dipentene. Terebene, when pure, is a colorless or a yellow, oily liquid. It is readily soluble in ether, less so in alcohol, and almost insoluble in water. It has been used in medicine as an expectorant in doses of from four to six minims, and as a local remedy.

Terpin Hydrate.—On leaving oil of turpentine in contact with the air for some time, it gradually changes into terpin hydrate, $C_{10}H_{18}$-$(OH)_2.(H_2O)$. This body is more easily obtained by agitating, for a day or two, a mixture of eight parts of turpentine and two of nitric acid, previously diluted with alcohol. Terpin hydrate occurs in large rhombic crystals. It is easily soluble in alcohol (10 parts), slightly soluble in water (250 parts), and sparingly so in chloroform, carbon disulphide, and ether. It melts at 116° C., giving off water and being converted into anhydrous terpin, $C_{10}H_{18}(OH)_2$. It is a crystalline body, fusing at 105° C. and subliming at about 250° C. (480° F.).

It rapidly absorbs water to form terpin hydrate, which behaves like a diatomic alcohol. It is dehydrated by P_2O_5 and converted into terebene and colophene. It is employed in medicine as an expectorant, in doses of from two to three grains. It may be given in as large as twenty- to thirty-grain doses.

Terpinol.—By boiling together terpin and water, acidulated with sulphuric acid, terpinol is obtained. It may be formed from turpentine by leaving it in contact with concentrated hydrochloric acid, or by passing HCl gas through a solution of terpin in alcohol and ether. By treating the resulting terebinthine dihydrochloride with boiling water, or with a solution of KOH, it decomposes, with the formation of terpinol.

Terpinol occurs as a colorless, oily liquid, with an odor resembling rosamin or hyacinths, having a sp. gr. of 0.852. Terpinol is not a single body, but is said to be a mixture of *terpinene, terpinolene, dipentene*,—all having the formula $C_{10}H_{16}$,—and an alcohol called *terpineol*, $C_{10}H_{17}OH$. The graphic formulæ of these compounds are as follows:

$$
\begin{array}{cc}
\text{H} & \text{H}_2 \\
| & || \\
\text{C} & \text{C} \\
\end{array}
$$

```
      H   H2
      |   ||
  H   C   C       H  CH3
  |   |   \       |   |
H—C—C       C—C—C—CH3
  |   ||   /      |
  H   C—C         CH3
      |   |
      H   H
```
Pinene.

```
          H2  H2
          |   |
  H       C — C        H
  |      /     \       |
H—C—C            C—C=C—C—H
  |      \     /    |  |  |
  H       C — C     H  H  H
          |   |
          H2  H2
```
Terpinin.

```
              H2  H  OH
              ||  ||  /
              C — C
      H      /     \       H
      |     /       \      |
    H—C—C             C—C—C—C—H
      |     \       /  ||  ||  |
      H      C — C     H2  H2  H
           /  |   |
          HO  H   H2
```
Terpin.

```
          H   H  OH
          |   |  /
          C — C
      H  /     \        H
      | /       \       |
    H—C—C        C—C—C—C—HH2O
      | \       / ||  ||  |
      H  C — C    H2  H2  H
        /  |   |
       H  OH  H2
```
Terpin Hydrate.
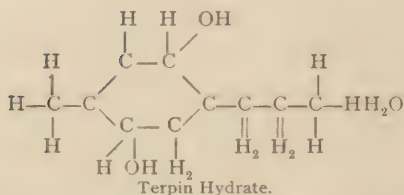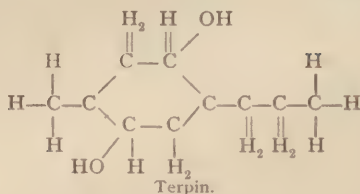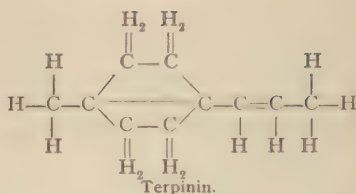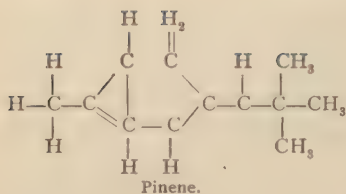
Terpinol is soluble in alcohol and ether, but insoluble in water. It has been employed in medicine as an expectorant, in doses of from 10 to 15 minims (600 to 900 milligrams).

Caoutchouc, or **india-rubber,** is the dried, milky juice of several tropical trees of the *Hevea* species. The fresh juice is acid. It is a mixture of several hydrocarbons which are insoluble in alcohol and water, but soluble in ether, benzene, chloroform, carbon disulphide, and turpentine. When cold, it is hard and tough, but on heating it becomes soft, elastic, and finally melts, and on cooling remains soft and viscid. It is much used in making elastic, waterproof fabrics, elastic tubing, etc., and is acted upon by but few reagents. The black color of the commercial article is due to smoke and partial decomposition.

Caoutchouc combines with sulphur. **Vulcanized** india-rubber is obtained by mixing it intimately with sulphur, by the aid of carbon disulphide, to the extent of two or three per cent., and afterward heating. Common white-rubber goods, as rubber tubing, etc., are also mixed with oxide of zinc and other impurities to a very large extent, in some cases but a small percentage of rubber being used. When mixed with about half its weight of sulphur, a hard, horny

mass called **vulcanite, or ebonite,** is produced, which is used in the manufacture of combs, cheap jewelry, etc. When heated, caoutchouc decomposes, but does not volatilize.

Gutta-percha is the hardened, milky juice of *Isonandra gutta,* a tree growing in some parts of India. It resembles caoutchouc, but is harder and less elastic. In hot water it becomes quite soft, and can be molded into any shape, which it retains on cooling. With solvents and high temperatures it behaves like caoutchouc.

Volatile or Essential Oils.—Volatile oils are those approximate principles to which, in the majority of cases, the odors of plants are due. They are extremely variable in composition, but many of them belong to the terpene series of hydrocarbons. The principal characteristics of these essential oils are their odors, variations in the rapidity of oxidation, and physical properties. They are soluble in alcohol, ether, benzene, petroleum naphtha, chloroform, carbon disulphide, paraffin, other volatile oils, and in the fixed oils. They may be classified as follows:

1. Oils consisting chiefly of terpenes, $C_{10}H_{16}$, and their oxidized products; such as turpentine, oil of lemon, and the oils of bergamot, birch, chamomile, caraway, hops, juniper, myrtle, nutmeg, orange, parsley, pepper, savin, thyme, tolu, and valerian.

2. Oils consisting chiefly of sesqui-terpenes or cedrenes, $C_{15}H_{24}$, and their oxidized products; such as the oils of cedar, cubebs, cloves, rosewood, calamus, cascarilla, and patchouly.

3. Oils consisting chiefly of aromatic aldehydes and allied bodies; such as the oil of almonds and the oil of cinnamon.

4. Oils consisting chiefly of ethereal salts or compound ethers; such as the oil of wintergreen or the oil of mustard.

Some of the more important oils of classes three and four are described in another place. The volatile oils of which the hydrocarbons form the main constituent, probably originally consisted of terpenes or cedrenes only. As usually met with, they are generally mixtures of the unchanged hydrocarbons, or **oleoptenes,** with the solid, oxidized, camphorized bodies termed **stearoptenes.** We frequently, also, find more highly oxidized bodies, called **resins.** On cooling the crude oil, the stearoptenes often crystallize out. On distilling the oils, the more volatile hydrocarbon first passes over, and may thus be separated from the oxidized solid portions. The more volatile portion of the distillate may be wholly freed from the oxidized bodies by distilling with free sodium, and thus the pure hydrocarbon is obtained.

The volatile oils of plants are extracted:

1. By pressure, as the oils of laurel, lemon, orange, bergamot, etc.

2. By distillation with water, or with a current of steam passed over the matter to be extracted. This is the most common method.

3. By first fermenting the part of the plant to be extracted. This is applied more especially to certain seeds, as the mustard, bitter almond, etc. After the fermentation, the oil formed is separated by distilling with water.

4. By solution in the fixed oils devoid of odor, such as poppy oil, oil of ben, etc.

The essential oils are usually liquid at ordinary temperatures, but deposit stearoptenes or camphors at low temperatures. They have, in most cases, highly characteristic odors, and a few have boiling points which are somewhat high. Some volatilize rapidly at ordinary temperatures. The essential oils are usually colorless or yellow when freshly prepared, but darken on exposure to air, and ultimately become sticky and resinous. Some oils have a well-marked blue color. Most of the essential oils are optically active, but their rotatory powers are variable and frequently change. The sp. gr. of essential oils ranges usually between 0.850 and 0.990. A few, however, have specific gravities outside these limits. The oxygenated and sulphuretted oils, as the oil of bitter almonds, wintergreen, mustard, etc., are heavier than water.

The essential oils are readily combustible. They are insoluble, or nearly so, in water; the water taking up, however, the characteristic smell and taste of the oils. They are freely soluble in alcohol, but are mostly precipitated on dilution with water. The separation is rarely, if ever, complete. The essential oils are miscible in all proportions in the fixed oils. Turpentine, petroleum naphtha, and carbon disulphide being insoluble in water, the essential oils may be separated from an aqueous liquid by agitation with these solvents.

The **analysis** of essential oils presents great difficulties. They are liable to adulteration with alcohol, chloroform, and turpentine.

Alcohol in essential oils may be detected by gradually adding dry $CaCl_2$, agitating, and warming the mixture in a water-bath. If alcohol is present in larger proportions than mere traces, a heavy, liquid layer will be formed at the bottom of the tube. Anilin red is insoluble in essential oils if pure and free from alcohol, but in the presence of a small proportion of alcohol the addition of anilin red colors them a deep red.

Chloroform may be detected by dissolving the oil in alcohol and warming the liquid with zinc and dilute sulphuric acid. Water is added, and the aqueous liquid is separated and tested for chlorides with $AgNO_3$ and HNO_3. The precipitation of AgCl proves the presence of chloroform in the oil.

A large number of volatile oils are employed in medicine either in a pure state or in the form of saturated aqueous solutions, called **medicated waters.** Solutions in alcohol, 1 in 5, are termed **essences ;** 1 in 50 are termed **spirits.**

THE CAMPHORS.

The camphors are a class of white, odorous, volatile oxidation products, or stearoptenes, mostly derived from the terpenes. Some of them, Japan camphor and carvol, $C_{10}H_{14}O$, are ketones, while most of them are alcohols. The most important camphors are the following :

Common Japan camphor, camphora (U. S. P., Br.), $C_{10}H_{16}O$, is obtained in China and Japan by distilling the branches and leaves of *Laurus camphora* with water. It is a white, translucent, crystalline mass, having a powerful, peculiar, pungent odor and taste. It is readily purified by sublimation at 205° C. (401° F.). It melts at 175°C. (347° F.) and burns with a smoky flame. Camphor is very slightly soluble in water, but readily soluble in alcohol, ether, acetic acid, benzene, chloroform, carbon disulphide, fixed and essential oils. **Aqua camphoræ** and **tinctura camphoræ** are official. Camphor enters into the composition of **linimentum camphoræ, linimentum saponis,** and **tinctura opii camphorata.**

Camphor forms a large number of decomposition products and derivatives under the action of reagents, but we shall notice but one of these.

Camphor monobromide, camphora monobromata (U. S. P.), $C_{10}H_{15}BrO$, is prepared by adding bromine to a solution of camphor in chloroform, by which camphor dibromide is obtained. This compound is unstable, and, on standing, sets free hydrobromic acid and forms monobromated camphor, which crystallizes in colorless, prismatic needles or scales, permanent in the air, having a mild, camphoraceous odor and taste and a neutral reaction. Its solvents are essentially the same as those of camphor. It melts at 76° C. (168.8° F.), boils at 274° C. (525° F.), and is volatilized with partial decomposition. In medicine it is used as a sedative, cardiac stimulant, etc.

Borneol, or **Borneo camphor,** has the formula $C_{10}H_{17}OH$. Isomeric with borneol are linalool and geraniol.

Linalool, $C_{10}H_{17}OH$, is a monatomic alcohol found either free, or as an ether, in oil of lavender, bergamot, spike, coriander, and lanalol. It is a colorless, fragrant liquid, of sp. gr. 0.878 and boiling at 197° C. (386.6° F.).

Geraniol, $C_{10}H_{17}OH$, is the chief constituent of Turkish geranium

oil, and is found in oil of rose, oil of citronella, oil of lavender, and oil of eucalyptus. It is a colorless liquid, with a fragrant, rose-like odor, boiling at 230° C. (446° F.).

Eucalyptol, $C_{12}H_{20}O$, is a colorless liquid, boiling at 175° C. (347° F.) and possessing an aromatic odor. It is contained in the leaves of the *Eucalyptus globulus*, a tree growing in Tasmania. On account of its supposed effect upon miasmatic atmospheres, it has been cultivated in southern Europe, the United States, and northern Africa. By distilling eucalyptol with phosphorus pentachloride, PCl_5, **eucalyptin,** $C_{12}H_{18}$ (according to some authors, $C_{10}H_{16}$), is obtained. Eucalyptol is slightly soluble in water, but soluble in alcohol. The oil has feeble antiseptic properties, and has been used in bronchitis, cystitis, and in intermittent fever.

Citral, $C_{10}H_{16}O$, is a golden-yellow liquid found in oil of lemon.

Citronellal, $C_{10}H_{18}O$, is a colorless, oily liquid found in oil of citronella and oil of lemon.

Menthol * (U. S. P., Br.), or **menthyl alcohol,** $C_{10}H_{20}O$, is a white, solid, crystalline body, occurring in oil of peppermint and possessing a strong odor of this plant. It melts at 43° C. (109.4° F.) and boils at 212° C. (413.6° F.). Menthol is soluble in alcohol and the essential oils.

Thymol (U. S. P., Br.), **Methyl-propyl-phenol.**—$C_6H_3 \begin{cases} OH \\ CH_3 = \\ C_3H_7 \end{cases}$

$C_{10}H_{14}O$. Thymol is a camphor or stearoptene of oil of thyme. It is also contained in the volatile oil of horse-mint. It is extracted by agitating the oil with a solution of NaOH. The aqueous layer is separated and treated with a dilute acid, when the thymol separates as an oily layer. The better plan is to collect the crude oil and subject it to low temperature, when the thymol crystallizes out. It may be purified by recrystallization from alcohol. Thymol is a phenol, and resembles carbolic and cresylic acids in its general properties. It is a powerful antiseptic, being ten times more effective than carbolic acid. It acts as an expectorant on the mucous membranes, but it does not irritate the skin like carbolic acid. Thymol occurs in large, colorless crystals, having an aromatic odor and a burning taste. It melts at 50° C. and boils at about 230° C. It is scarcely soluble in water, requiring about 1200 parts of cold or 900 parts of boiling water for solution. Alcohol dissolves its own weight of thymol, and the greater part separates again on dilution with water. A solution of four grains of

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* Although really an alcohol, it is classed here with the camphors, owing to physical properties.

thymol to a fluidounce of alcohol is miscible with water in all proportions. It is sparingly soluble in glycerin, requiring 120 parts for solution. It is readily soluble in ether, chloroform, petroleum spirit, and oils. When triturated with camphor, a syrupy liquid is obtained, which is readily miscible with vaseline or similar preparations. Thymol is soluble in strong acetic acid. A delicate test for thymol consists in dissolving a little of the sample in 1 c.c. of glacial acetic acid, and adding 5 or 6 drops of strong sulphuric or 1 drop of nitric acid, when, if thymol be present, it first becomes green, and then, on shaking, a fine blue color makes its appearance. Phenol gives a violent-red color, but menthol, camphor, borneol, and salicylic acid give no color when similarly treated.

Cantharidin, $C_{10}H_{12}O_4$, is the active principle of cantharides, or Spanish fly, and of other vesicating insects. It has many of the properties of camphor. When pure, it forms four-sided prisms, but frequently deposits in scales of micaceous appearance. It melts at about 200° C. (392° F.), and sublimes in white flakes, which strongly irritate the eyes, nose, and mouth, and condense in lustrous, rectangular prisms. Cantharidin has feeble acid properties. It is insoluble in water, but dissolves in caustic alkalies to form cantharidates. Cantharidin may be crystallized from hot hydrochloric acid, but is soluble in strong sulphuric acid, being reprecipitated on dilution. Cantharidin dissolves readily in alcohol, ether, acetic ether, and chloroform. It is nearly insoluble in naphtha and carbon disulphide. It is extracted from acidulated solutions by agitation with chloroform. Cantharidin has well-marked poisonous properties, and the beetles containing it have been administered with criminal intent. In toxicological inquiries the contents of the stomach and intestines should be carefully examined for the iridescent green wing-cases of the beetle. If the tincture has been taken, the only available test is the isolation of the cantharidin with chloroform, and the application of the residue to a sensitive part of the skin. The mixture of one part of cantharidin in 500 of lard produces very strong vesication, and 0.001 gm. of cantharidin dissolved in a drop of alcohol also produces marked vesication.

RESINS, OLEORESINS, GUM-RESINS, BALSAMS.

Many of the bodies of the terpene and essential-oil series above mentioned, when exposed to the air undergo a process of oxidation or hardening, become viscid or solid, and exhibit an acid reaction.

Such bodies, when brittle and solid, are called **resins** ; when com-

28

posed of unoxidized oils mixed with resins, they are called **balsams** ; when the resins exist in the juices of plants mixed with gum, sugar, etc., they are called **gum-resins.** Each one of these bodies is generally a mixture of several bodies, and, therefore, no definite chemical formulæ can be given. They are insoluble in water, but soluble in strong alcohol, turpentine, and glycerin ; many are soluble in ether and benzene (separation from gums) ; many are weak acids, whose alkaline salts form the **resin soaps** of the market. Many resins are used in medicine, in the manufacture of varnishes, sealing-wax, and salves. The resins are soluble in alcohol.

The resins soften when heated, but do not vaporize. The separation of resins from volatile oils and acids is effected by **distillation** with water : from gums, by **fusion** and straining at 100° C. (212° F.) ; from each other, as well as from foreign substances, by properly selected **solvents.**

Under the name of resins the following substances are classed :

Amber, colophony (rosin), copal (anime), dammar, lac, Burgundy pitch, mastic, and sandarac, which are used in the arts for making varnish, and for other purposes.

The following are some of the resinous substances used in medicine : **Arnicin,** from arnica flowers ; **castorin,** from castoreum ; **cannabin,** from cannabis indica ; **dragon's blood,** an exudation from the fruit of *Calamus draco ;* **elemi,** a resin from Central America, an exudation from the *Amyris elemifera ;* a resin found in ergot of rye ; **guaiacum,** an exudation from the wood of the *Guaiacum officinale ;* **jalap,** the resin of jalap root ; **labdanum,** an exudation from the bark of several varieties of the *cistus,* grown in Greece ; **podophyllin,** from the Mayapple root ; **pyrethrum,** from pellitory root ; and **rottlerin,** from the kamala, a shrub grown in the East Indies.

Dammar is the exuded and hardened sap of the *Dammara orientalis,* a coniferous tree growing in the East Indies, Australia, and New Zealand. It is also used in the manufacture of varnish.

Lac is a resinous incrustation produced on the bark of the twigs of various tropical trees by the puncture of the '' lac insect.'' This crude gum is called '' stick lac '' in commerce. **Shell-lac,** or shellac, is formed by melting, straining, and drying it in thin sheets.

In the preparation of shellac the coloring matter is separated, and is sold under the name of **lac dye.**

Shellac is easily soluble in alcohol. It is used extensively in the manufacture of varnish, lacquers, sealing-wax, etc.

Mastic is an exudation from the bark of certain trees found in the island of Chios in the Mediterranean. It occurs in pale-yellow, transparent, brittle tears, soluble in alcohol and turpentine, and is

used for making varnish. It is official, and enters into **pilulæ aloes et mastiches.**

Guaiacum is a brittle, pulverizable solid, of a reddish-brown color. The gum dissolves in alcohol. It readily undergoes oxidation, producing bright colors. A mixture of the official tincture and oil of turpentine is frequently employed as a reagent for detecting blood in urine, with which it strikes a blue color.

Only the most common resins can be described.

Common resin, rosin, colophony, is the residue left by distilling the balsam or crude turpentine of the pine with water. Turpentine distils off and leaves a yellow or brown, brittle, shining mass, which, when melted, forms the commercial rosin. It usually has a sp. gr. of about 1.04 to 1.10. It is nearly tasteless, but leaves a characteristic nauseous after-taste. It is insoluble in water, but is soluble in alcohol, ether, chloroform, and in the fixed and volatile oils. It is soluble in caustic, and even in carbonated alkalies, forming soaps soluble in water. Colophony is composed chiefly of several resin acids, the chief of which is abietic acid, $C_{44}H_{62}O_4$. Sylvic acid, $C_{20}H_{30}O_2$, exists in small quantities.

It may be detected in mixtures by boiling 5 gm. of the mixture with 20 c.c. of pure nitric acid, diluting when cold with an equal volume of water, and adding ammonia. If resin be present, a blood-red solution is produced. Rosin is used in the manufacture of varnishes, sealing-wax, lamp-black, the common yellow soaps, cerates, and plasters.

Copal, or anime, is a yellow, hard, brittle, more or less transparent solid, found on the coast of Africa, and is dug out of the soil by the natives. It is a fossil resin of recent origin. It is very hard, and soluble with great difficulty in alcohol and essential oils. It makes the best resin varnishes.

Amber is also a **fossil resin,** found on the shores of the Baltic in Prussia. It is a very hard, tough, and transparent or translucent yellow solid. It is used for making beads, mouthpieces of pipes, and for the manufacture of superior varnish.

Oleoresins are mixtures consisting of an oil, either fixed or volatile, holding resin and sometimes other substances in solution. They are generally soluble in ether, and on evaporation of the ether they are left in a semifluid state. On distillation they yield an oil, while the resin is left behind.

The best-known **oleoresins** are the oleoresins of aspidium, male fern, capsicum, cubeb, copaiba, lupulin, pepper, ginger, frankincense, Canada balsam, and Canada pitch. They are usually extracted from the plants with ethylic ether, using 150 parts of ether for 100

parts of the plant.   (U. S. P. method.)   The ether is then distilled off and the oleoresin kept in a well-stoppered bottle.

The principal **gum-resins** are aloes, ammoniacum, asafetida, myrrh, scammony, gamboge, galbanum, olibanum, and euphorium. All but the last are official.   They occur in commerce mostly as compact masses of a yellow or brown color, composed of tears glued together into a hardened, gummy mass.

They are usually brittle enough to be pulverized, and are soluble in alcohol or ether.   When rubbed with water in a mortar, they form milk-white emulsions.   The most of them are soluble in caustic alkalies.

Gum-benzoin, as it is frequently called, is a balsamic resin, and occurs as rectangular blocks, which consist of milk-white tears agglutinated by a brown resin.   It has a pleasant, balsamic odor, and is soluble in alcohol, forming tincture of benzoin.   It contains from twelve to twenty per cent. of benzoic acid, which can be sublimed from it by a gentle heat.   It usually contains a small quantity of cinnamic acid and sometimes vanillin.   It contains several resins.

The chief **balsams** are balsams of Peru, storax, and tolu.

Balsams of Peru, storax, and tolu contain cinnamic ethers, resinous matter, and volatile oils.   Benzoic acid is found in balsams of Peru and tolu.

They are all soluble in alcohol.

THE BENZENE OR AROMATIC HYDROCARBONS, OR CYCLO-HYDROCARBONS.

$$C_nH_{2n-6}.$$

This series of hydrocarbons is called the benzene series, because they are all derivatives of benzene; and aromatic, because most of them have an aromatic odor and taste.

The compounds of this series differ from all others thus far mentioned, in the structure of their molecules, in that the carbon atoms are arranged in the form of a closed chain, or cycle, at the angles of a regular hexagon:
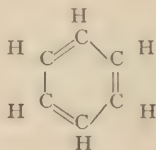
also written :

i. e., every carbon atom is the equivalent of every other, while in the other hydrocarbons we have noticed a difference between the end ones and the others. The H atoms in benzene are all alike in behavior. We arrive at the idea that the C atoms are in a closed chain by the following facts. Benzene takes up two, four, or six atoms of H, Cl, or Br, according to the conditions of the experiment. Benzene thus becomes, in the first case, under the prolonged action of HI, hexa-hydro-benzene, C_6H_{12}, but the continued action of HI does not impart to it any more H atoms. If the carbon atoms were arranged in an open chain, it would become C_6H_{14}.

$$H_3C - C - C - C - C - CH_3$$
$$\begin{matrix} \| & \| & \| & \| \\ H_2 & H_2 & H_2 & H_2 \end{matrix}$$
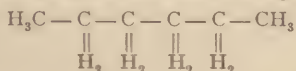
The **hexachloride** of benzene, $C_6H_6Cl_6$, when once formed, refuses to take up more chlorine. The same is true of the hexabromide. In order to give an explanation of these facts, it is necessary to assume one of the following graphic formulæ as the proper arrangement of the C atoms in its molecule :
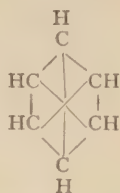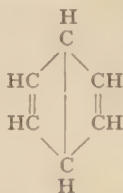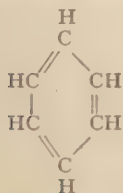
The first one of these three formulæ is the one suggested by Kekulé in 1866, and is the one now generally accepted.

When di-derivatives from benzene are formed, we find three possible isomers. If, now, we examine the possible formulæ, we find the following possible groupings, in the case of the alcohols:
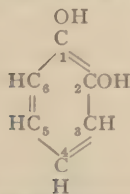
Ortho-dihydrobenzene, or Pyrocatechin.
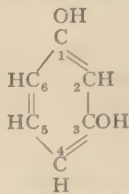
Meta-dihydrobenzene, or Resorcin.
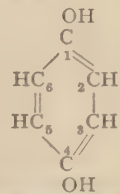
Para-dihydrobenzene, or Hydroquinone.

In like manner there are three dichlorides, three dibromides, and three dinitrobenzenes, but no more. By inspection it will be seen that

the two hydroxyls could not be placed in other relative positions than in
the above three formulæ.   For if the OH groups were placed on the C
atoms 1 and 6, we should have the same compound as if placed on 1
and 2 ; or if placed on 1 and 5, the effect would be the same as if
placed on 1 and 3.   The benzene hydrocarbons are, as a rule, easily
nitrated, producing mon-, di-, or tri-derivatives according to the con-
ditions.   Hydrocarbons of this series oxidize with difficulty.   Owing
to this difficulty of oxidation, derivatives from benzene usually pass
through the body, or are eliminated in the urine with the nucleus
intact.   For example : Salicylic acid and phenol or carbolic acid ap-
pear in the urine unchanged.   The benzene hydrocarbons are mostly
liquids, insoluble in water, but soluble in alcohol and ether, and distil
without decomposition.   The higher members of this series are solid
and crystalline.   They all burn with a luminous, smoky flame.   The
homologues of benzene may be regarded as derived from it by the sub-
stitution of one or more hydrocarbon radicals for hydrogen atoms.

A few hydrocarbons of the benzene series are the following :

Benzene, C_6H_6, ... boils at 81° C (177.8° F.).
Toluene, or methyl-benzene, $C_6H_5CH_3$, ...   "   111° C. (231.8° F.).
Xylene, or dimethyl-benzene, $C_6H_6(CH_3)_2$, ...   "   140° C. (284° F.).
Pseudocumene, or trimethyl-benzene, $C_6H_6(CH_3)_3$, . .   "   166° C. (330.8° F.).
Durene, or tetramethyl-benzene, $C_6H_6(CH_3)_4$, ...   "   190° C. (374° F).
Amyl-toluene, or pentamethyl-benzene, $C_6H_6(CH_3)_5$, .   "   231° C. (447.8° F.).

The benzene series of hydrocarbons are remarkable for the large
number of isomers they present.

Benzene, Benzol.—C_6H_6.   The first member of this series of
hydrocarbons is of considerable importance.   This compound, C_6H_6,
must not be confounded with benzine, which is a trade name, and is
used to designate a mixture of hydrocarbons having a variable compo-
sition and boiling point, and generally known under the name of
naphtha.   Benzene was formerly prepared by distilling benzoic acid
with lime.   It is now obtained in large quantities by the distillation
of coal-tar from gas-works.

In the primary distillation of coal-tar the lighter portion of the distil-
late is preserved.   It is first washed with H_2SO_4, and then with a solution
of caustic soda and redistilled.   That portion which goes over between
80° and 85° C. (176° and 185° F.) is retained.   This forms the com-
mercial benzene, which is a mixture of benzene, toluene, and other
hydrocarbons.   Benzene is a colorless, limpid, highly refractive liquid,
with a peculiar odor and taste.   Its sp gr. is o.86.   It crystallizes at
4.5° C. and boils at 80.5° C. (176.9° F.).   It burns with a smoky
flame, is insoluble in water, but soluble in ether, alcohol, acetone, and
naphtha.   It dissolves sulphur, phosphorus, iodine, resins, fats,

caoutchouc, gutta-percha, and many of the alkaloids. Benzene unites with chlorine, iodine, and bromine to form either addition or substitution products, according to the conditions. It also combines with sulphuric acid to form sulphobenzene when the anhydrous acid is used, or phenolsulphonic acid when ordinary H_2SO_4 is used. With fuming nitric acid, benzene forms a yellowish-red liquid, **nitrobenzene**, $C_6H_5NO_2$. If benzene is boiled with fuming nitric acid, or with a mixture of nitric and sulphuric acids, **dinitrobenzene**, $C_6H_4(NO_2)_2$, is formed.

The higher homologues of benzene are of interest only to the chemist. By passing the vapor of benzene through a red-hot tube, it is partially decomposed, with the separation of H_2 and the formation of diphenyl.

$$2C_6H_6 = C_6H_5 - C_6H_5 + H_2.$$
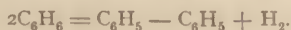
The same compound is formed by the following reaction :

$$2C_6H_5Br + Na_2 = C_6H_5 - C_6H_5 + 2NaBr.$$
Monobrombenzene.   Diphenyl.

Diphenyl, , crystallizes in large plates, fusing
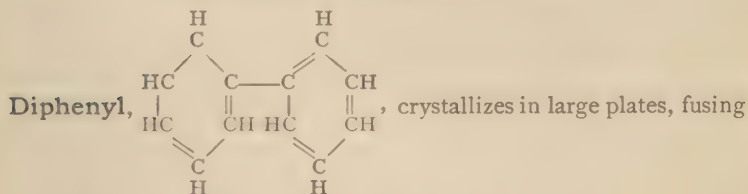
at 70.5° C. (159° F.) and boiling at 254° C. (489° F.). It is found in the products of the distillation of gas-tar coming over at about 260° C. Diphenyl forms a large number of substitution derivatives.

The benzene nucleus is sometimes met with in the condensed form— *i. e.*, two or more of the nuclei fuse together with two C atoms common to the two adjoining groups.

Two benzene molecules thus condensed give **naphthalene** :

     or
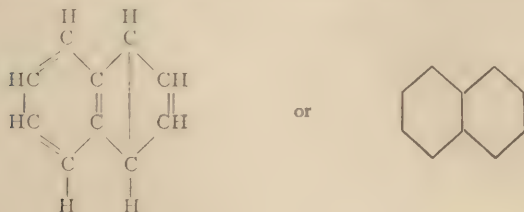
Three benzene molecules thus condensed give a molecule of **anthracene :**
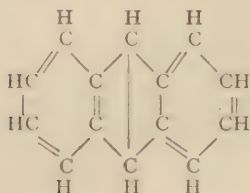
Naphthalene, $C_{10}H_8$, **naphthalinum** (U. S. P.), is obtained from coal-tar by distillation between 180° C. and 220° C. (356° F. to 428° F.). It comes over with heavy oils, but crystallizes from them in white, glistening, leafy crystals, of a peculiar, aromatic odor and burning taste ; it melts at 79.2° C. (174.5° F.), is insoluble in water, but soluble in hot alcohol, ether, or benzene.

The principal interest of naphthalene to the physician is its value as an antiseptic dressing for wounds. For this purpose it must be thoroughly purified by recrystallization from alcohol, or distillation with steam. It is used as an intestinal antiseptic, and as a moth-destroyer under the name of **coal-tar camphor.** Naphthalene takes up hydrogen quite readily to form the dihydride $C_{10}H_8H_2$, the tetrahydride $C_{10}H_8H_4$, the hexahydride $C_{10}H_8H_6$, and the decahydride $C_{10}H_8H_{10}$. It also forms a dichloride, $C_{10}H_8.Cl_2$, and a tetrachloride, $C_{10}H_8Cl_4$. This last compound, when oxidized with nitric acid, yields phthalic acid, $C_6H_9(COOH)_2$.

Anthracene, $C_{14}H_{10}$, is a white, crystalline body obtained from coal-tar, distilling above 360° C. (680° F.). Its constitution is shown by the graphic formula above.

The chief interest of anthracene is that it serves as the starting point in the manufacture of **alizarin,** $C_6H_4 <^{CO}_{CO}> C_6H_2(OH)_2$, or artificial madder. Its solutions possess a beautiful blue fluorescence, a property observed in many of the heavier hydrocarbons derived from coal-tar and petroleum—i. e., their solutions are colorless or yellowish by transmitted light, but when viewed by reflected light appear bluish. The phenomenon is well seen in solutions of quinine sulphate.

By oxidation anthracene yields **anthraquinone.**
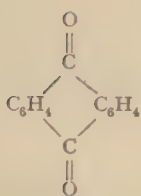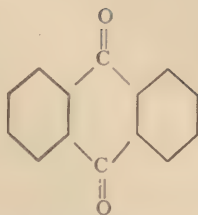
It occurs as yellow, needle-like crystals, fusing at $273°$ C. ($523°$ F.).

DERIVED COMPOUNDS.

Addition and Substitution Products.—Addition products are formed by the direct combination of an unsaturated molecule with one or more radicals. They are readily formed from unsaturated hydrocarbons like the olefins or acetylenes. One molecule of the hydrocarbon always unites with two or four monivalent atoms or radicals, or with their equivalent in polyvalent radicals. It is especially the atoms of the chlorine group, or their hydracids, which are most easily added ; but hydrogen, as well as other hydrocarbon radicals, may also be added.

Substitution products are formed by an exchange of one or more hydrogen atoms for simple or compound radicals. Indeed, we may regard all the complex organic bodies as made up in this way. Thus, ethane, C_2H_6, may be regarded as a molecule of methane, CH_4, in which one hydrogen atom has been displaced by the radical CH_3. Thus :
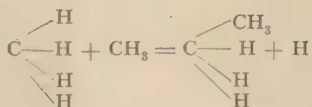
Synthesis of Organic Compounds.—The principal interest of chemists in recent years, in the department of organic chemistry, is centered upon the synthesis of organic compounds. By these synthetical methods the chemist imitates, to a limited extent, the process of animal and vegetable organisms. The natural tendency of all organic compounds is to break up complex molecules and form simpler ones, while it is the aim of synthetical methods to reverse this process and build up complex molecules from simpler radicals, adding little by little until the structure is complete.

29

It is principally from synthetical reactions that we can arrive at a knowledge of the structure of complex organic bodies. With these synthetical methods chemists have succeeded in the artificial production of alizarin (the coloring matter of madder), indigo, salicylic acid, and the great variety of anilin colors, which are among the greatest achievements of modern science.

The Action of Reagents on Organic Compounds.—The reactions of organic compounds are so different from those of inorganic chemistry that we introduce here a few of the principal reagents used and their behavior. Cl, Br, and I act upon unsaturated hydrocarbons by direct addition. With saturated hydrocarbons they substitute for H :

$$C_6H_6 + 3Cl_2 = C_6H_6Cl_6.$$
$$CH_4 + Cl_2 = CH_3Cl + HCl.$$
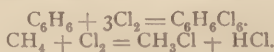
In the presence of water these act as oxidizing agents.

$$H_2O + Cl_2 = 2HCl + O.$$

HCl and HBr substitute Cl or Br for alcoholic hydroxyl.

$$\underset{\text{Alcohol.}}{C_2H_5OH} + HCl = \underset{\substack{\text{Ethyl}\\\text{Chloride.}}}{C_2H_5Cl} + H_2O.$$

$$\underset{\substack{\text{Lactic}\\\text{Acid.}}}{CH_3\!-\!CHOH.COOH} + HBr = \underset{\substack{\text{Mono-brom-propionic}\\\text{Acid.}}}{CH_3\!-\!CHBr\!-\!COOH} + H_2O.$$

$$\begin{array}{c}C_2H_5\\ \diagdown\\ \diagup\\ C_2H_5\end{array}\!\!\!O + 2HCl = \begin{array}{c}C_2H_5Cl\\ \\ C_3H_5Cl\end{array} + H_2O.$$
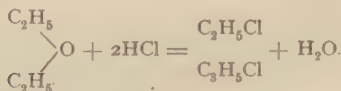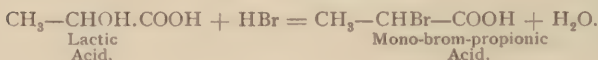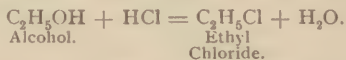
With unsaturated hydrocarbons they combine directly.

$$C_2H_4 + HCl = C_2H_5Cl.$$

III acts similarly to the above, but at higher temperatures it substitutes backward —*i. e.*:

$$CH_2ICOOH + HI = CH_3COOH + I_2.$$

In compounds containing alcoholic hydroxyl, HI acts as a reducing agent, removing the oxygen.

$$\underset{\text{Glycerin.}}{C_3H_5(OH)_3} + 5HI = \underset{\text{Iso-propyl-iodide.}}{C_3H_5(H_2I)} + 3H_2O + 2I_2.$$

The free iodine acts as an oxidizing agent unless it be absorbed. This is usually done by adding some free phosphorus, with which it forms PI_3, which, in the presence of water, again forms HI.

H_2SO_4 acts upon the alcohols of the paraffin series by substituting HSO_4 for HO. It acts upon the hydrocarbons of the benzene series by substituting HSO_3 for H.

$$\underset{\text{Alcohol.}}{C_2H_5OH} + H_2SO_4 = \underset{\substack{\text{Ethyl-sulphuric}\\\text{Acid.}}}{C_2H_5HSO_4} + H_2O.$$

$$C_6H_6 + H_2SO_4 = C_6H_5HSO_3 + H_2O.$$
<div align="center">Benzene.   Phenyl-sulphonic.
Acid.</div>
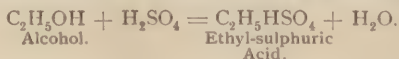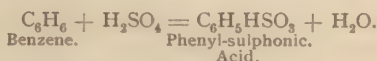
Under certain conditions we may have the following reactions :

$$2C_2H_5OH + H_2SO_4 = (C_2H_5)_2(SO_4) + 2H_2O.$$
<div align="center">Ethyl-sulphate.</div>

$$2(C_6H_6) + H_2SO_4 = 2(C_6H_5)SO_2 + 2(H_2O).$$
<div align="center">Phenyl-sulphonate.</div>
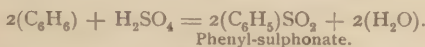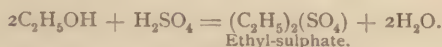
HNO_3 forms nitric ethers with the alcohols of the paraffin series.

$$C_2H_5OH + HNO_3 = C_2H_5NO_3 + H_2O.$$
<div align="center">Ethyl nitrate.</div>

$$C_3H_5(HO)_3 + 3HNO_3 = C_3H_5(NO_3)_3 + 3H_2O.$$
<div align="center">Glycerin.   Nitroglycerin,
Glycerin Trinitrate.</div>
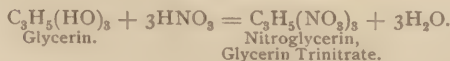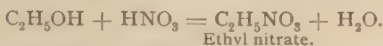
With aromatic hydrocarbons it forms nitro- substitution products.

$$C_6H_6 + HNO_3 = C_6H_5NO_2 + H_2O.$$
<div align="center">Benzene.   Nitrobenzene.</div>
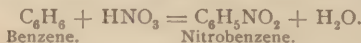
H_2SO_4 and HNO_3, therefore, act alike on certain organic bodies.
NaOH and KOH in aqueous or alcoholic solution decompose (saponify) the compound ethers, reproducing the corresponding alcohols.

$$C_2H_5OC_2H_3O + KOH = C_2H_5OH + KC_2H_3O_2.$$
<div align="center">Acetic Ether.   Alcohol.   Potassium
Acetate.</div>

They substitute HO for Cl, Br, or I in haloid ethers.

$$C_2H_5Cl + KOH = C_2H_5OH + KCl.$$
<div align="center">Ethyl-chloride.   Alcohol.</div>

When fused with organic bodies, NaOH and KOH act as oxidizing agents, exchanging O for H, the H being set free.

$$C_2H_5OH + KOH = C_2H_3O_2K + 2H_2.$$
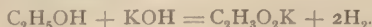
In such cases the tendency is always to form acids, with which they combine.
PCl_3 and PBr_3 and $POCl_3$ and $POBr_3$ substitute Cl or Br for OH in alcohols.

$$3C_2H_5OH + PCl_3 = 3C_2H_5Cl + H_3PO_3.$$
$$3C_2H_5OH + POBr_3 = 3C_2H_5Br + H_3PO_4.$$
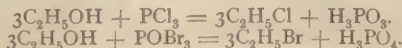
PCl_5 and PBr_5 can substitute Cl or Br for O, or they may act like free Cl and Br.

$$C_2H_4O + PCl_5 = C_2H_4Cl_2 + POCl_3.$$
<div align="center">Aldehyde.   Ethyl-chloride.</div>
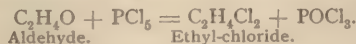
P_2S_5 substitutes S for O in the hydroxyl of alcohols and acids.

$$5C_2H_5OH + P_2S_5 = 5C_2H_5SH + P_2O_5.$$

As an illustration of the synthesis of organic compounds, we here introduce a few reactions, starting with the elements C and S.

If we pass the vapor of sulphur over heated charcoal we get CS_2. The vapor of CS_2 mixed with H_2S and passed over heated copper turnings forms methane, CH_4.

$$2Cu_2 + CS_2 + 2H_2S = 4CuS + CH_4.$$

When we pass a strong current of electricity between carbon poles in an atmosphere of H, we obtain acetylene.

$$C_2 + H_2 = C_2H_2.$$
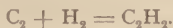
When acetylene is treated with nascent H, ethene is produced.

$$C_2H_2 + H_2 = C_2H_4.$$

C_2H_4 acted upon by HBr gives C_2H_5Br (ethyl-bromide).

C_2H_5Br, when treated with nascent H, gives ethane, C_2H_6.

If instead of the bromide we form the iodide of ethyl, and treat this with zinc-methyl, $Zn(CH_3)_2$, we obtain methyl-ethyl, or propane.

$$2C_2H_5I + Zn(CH_3)_2 = 2C_2H_5CH_3 + ZnI_2.$$
Ethyl-iodide.   Zinc-methyl.   Propane.
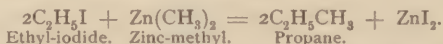
By starting with propyl-iodide, C_3H_7I, and treating this with KOH we obtain C_3H_6 (propene).

$$C_3H_7I + KOH = C_3H_6 + KI + H_2O.$$
Propyl-iodide.   Propene.
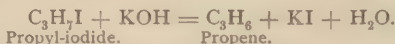
These reactions will show the methods of changing the hydrocarbons from one homologous series to another, and are introduced here merely as illustrations of the action of reagents.

DETERMINATION OF THE CONSTITUTION OF ORGANIC COMPOUNDS.

This is possible only when we know the behavior of the compound with reagents. This may be illustrated as follows: When we treat an ethereal solution of CH_3I with sodium, we set free the **methyl.**

$$CH_3I + Na = CH_3 + NaI.$$

This CH_3 must have one free bond of attraction, thus:

$$H-\overset{|}{\underset{H}{C}}-H$$

The vapor density of this gas is 15. The molecular weight, therefore,

is 30, or corresponds to C_2H_6; *i. e.*, the two methyl radicals unite by their free bonds, and we have $\begin{array}{c} C\equiv H_3 \\ | \\ C\equiv H_3 \end{array}$.

By treating C_2H_6 with chlorine, we form C_2H_5Cl. This, treated with KOH, gives C_2H_5OH, or **ethyl-alcohol.** As OH has taken the place of Cl in C_2H_5Cl, we conclude that the OH has gone in as hydroxyl. The hydrogen of this OH can be replaced with sodium or potassium, but none of the others in the molecule can be. This atom, therefore, has a different position in the molecule from the others. The relation of the carbon atoms is not destroyed by the above reaction, and therefore we arrive at the conclusion that the formula is $\begin{array}{c} C\equiv H_3 \\ | \\ C{=}H_2 \\ \diagdown OH. \end{array}$. Again, we have the reactions :

$$C_2H_5OH + HCl = C_2H_5Cl + H_2O;$$

i. e., we have the C_2H_5 and OH groups in alcohol. And again, if we treat C_2H_5Cl with nascent hydrogen, we obtain C_2H_6 and HCl. C_2H_6 we have seen above to be **di-methyl,** or $\begin{array}{c} C\equiv H_3 \\ | \\ C\equiv H_3 \end{array}$.

In **methyl-ether,** which is isomeric with alcohol, no one of the hydrogen atoms can be replaced with sodium or potassium. When we remove the oxygen atom with HI, the connection of the carbon atoms is broken, with the formation of compounds having one carbon atom only. Thus :

$$C_2H_6O + HI = CH_4O + CH_3I,$$
$$\text{or}$$
$$C_2H_6O + 2HI = 2CH_3I + H_2O.$$
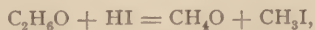
This shows that the oxygen atom in methyl-ether acts as a link between the two carbon atoms, as its removal breaks the molecule apart ; also that the hydrogen atoms are all alike in the molecule. Hence, the formula should be represented as follows : $H_3C{-}O{-}CH_3$.

The formula of **alcohol** would be represented as follows : $CH_3{-}CH_2OH$. In the same way we determine that the rational formula of **acetic acid** is $H_3C{-}\overset{\overset{\textstyle O}{\|}}{C}{-}OH$.

It is the aim of chemists to determine the rational formulæ of all organic bodies by such reactions. This has been done for most organic substances. When we know the structure of the molecule of the substance, we are able in many cases to construct it syn-

thetically. Thus, if we compare the following formulæ, we see a close resemblance :

Phenol.

Salicylic Acid.
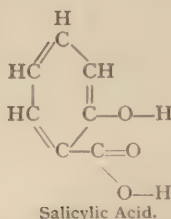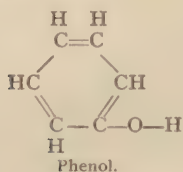
If we treat the first of these substances with sodium hydroxide, we obtain C_6H_5ONa. If we treat this at a high temperature with CO_2, this gas enters the molecule, CO going in with the NaO group to give C_6H_5COONa. The other O goes to the neighboring carbon atom and gives OH. Thus, **salicylic acid** is prepared from phenol.

Haloid Derivatives, or Haloid Ethers.—These substitution products are formed by the action of Cl or Br upon the paraffins, or by the action of HCl, HBr, or HI upon the corresponding alcohols. These compounds may be considered as chlorides, bromides, or iodides of the alcohol or alkyl radicals. When chlorine acts upon methane, the hydrogen is gradually displaced by chlorine, forming **methyl-chloride**, CH_3Cl, or **monochlormethane**; **dichlormethane,** CH_2Cl_2; **trichlormethane,** $CHCl_3$; **tetrachlormethane,** CCl_4.

Methyl-chloride, monochlormethane, CH_3Cl, is prepared on a large scale for use in freezing-machines by heating the hydrochloride of trimethylamin to 260° C. (500° F.).

$$3N(CH_3)_3HCl = 2CH_3Cl + 2N(CH_3)_3 + NH_2CH_3 + HCl.$$
Methylamin   Methyl-   Trimethyl-   Methylamin.
Hydrochloride.   chloride.   amin.
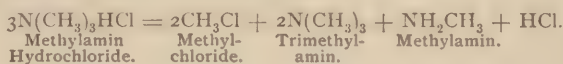
Trimethylamin is produced by distilling the refuse from the manufacture of beet-sugar. This is neutralized with hydrochloric acid and then heated as above.

Methyl-chloride is a colorless gas, slightly soluble in water, and having a sweetish taste and odor. It is a liquid below —22° C. (—7.6° F.). It burns with a greenish flame. It is obtained by passing gaseous HCl into methyl-alcohol, or by treating methyl-alcohol with a mixture of H_2SO_4 and NaCl. These solutions have been used externally for the relief of neuralgia.

Methyl-bromide and methyl-iodide are prepared by the action of phosphorus and bromine or iodine upon methyl-alcohol. They are both liquids at ordinary temperatures.

Dichlormethane, methylene chloride, CH_2Cl_2, is obtained, along with the other chlorine substitution products, by the action of Cl upon CH_4, or it may be obtained by the reduction of chloroform with nascent hydrogen. It is a colorless, oily liquid, boiling at 40° C. (104° F.), with an odor similar to that of chloroform. It is slightly soluble in water, is non-inflammable, and has been employed as an anesthetic. It is not safer as an anesthetic than chloroform.

Trichlormethane, Chloroform, Chloroformum (U. S. P., Br.).—$CHCl_3$. When methyl-chloride is acted upon by chlorine it produces a series of successive substitution products, one of which, **trichlormethane,** is known under the name of **chloroform.** It was discovered in 1831 by Soubeiran and Liebig. It is usually prepared, on a manufacturing scale, from common alcohol, as follows: In 24 parts of water dissolve 6 parts of chloride of lime, strain into a retort, heat to 40° C. (104° F.), and add 1 part of strong alcohol. A reaction soon sets in, developing sufficient heat to distil over the $CHCl_3$. This distillate is purified by shaking it with water, and then pure H_2SO_4 (free from HNO_3), which chars any hydrocarbons or empyreumatic substances. It is then freed from acid by agitation with lime, and from water with dry calcium chloride. Chloroform is now made on a large scale by the distillation of acetone with chloride of lime.

Chloroform is a colorless, mobile liquid, possessing a peculiar, sweetish, ethereal odor and taste. It boils at 60.8° C. (141.8° F.), and has a sp. gr. of 1.49 at 15° C. (59° F.) and 1.473 at 25° C. (77° F.). It is not miscible with water, is uninflammable in the air, and dissolves fats, resins, caoutchouc, sulphur, phosphorus, and iodine— the last with a violet-colored solution. Commercial chloroform is apt to be contaminated with alcohol, aldehyde, and lower substitution products, and thus readily becomes useless on keeping. Purified chloroform (U. S. P.) is prepared from the above by mixing it with sulphuric acid, agitating, drawing off the chloroform, neutralizing with a solution of sodium carbonate, again drawing off, adding lime, and finally distilling the chloroform on a water-bath and adding one per cent. of alcohol. **Chloral-chloroform** is the name sometimes applied to chloroform prepared from chloral by distilling with an alkali. It is so prepared because of its freedom from the impurities to which ordinary chloroform is subject. The best article for anesthetic purposes is prepared in this way. Pure chloroform must not affect litmus, must not color a mixture of H_2SO_4 and chromic acids green, must not turn brown with H_2SO_4 or KOH, and must not suddenly evolve inflammable gases when heated with alcoholic solution of potassium hydroxide. It should not give a precipitate with silver nitrate, nor a yellow color with a solution of potassium iodide. No foreign odor

should be observed on allowing a few drops to evaporate on the hand. Chloroform prevents putrefactive decomposition and fermentation.

Physiological Action.—When applied to the skin, chloroform acts as an irritant, and, if evaporation be retarded, as a vesicant. The vapor, when inhaled, produces anesthesia. When used for this purpose, it should be quite pure, and some air should be admitted with the vapor when administered. The fatal accidents that have occurred in its use as an anesthetic are due to a paralysis of the heart, and, in some cases at least, may be attributed to the exclusion of air from the lungs. It is safer with children and with women in parturition than with ordinary adults. It is eliminated slowly, and when injected hypodermically the effect is slow in making its appearance and lasts for several hours. It should be administered with caution to persons who are the subjects of organic heart or renal diseases.

Impurities.—Chloroform is likely to contain as impurities chlorine, aldehyde, and hydrochloric acid. Pure chloroform should leave no residue when a few drops are evaporated on a watch-glass. When shaken with an equal volume of water, the latter, when separated, should not affect litmus paper ; nor give a precipitate with $Hg_2(NO_3)_2$; nor liberate iodine from a solution of KI. A portion of it digested with a solution of KOH should not become dark (absence of aldehyde). If a dark color appears when 10 c.c. of chloroform are mixed with 5 c.c. of H_2SO_4 and allowed to remain in contact for twenty-four hours, it shows the presence of foreign substances of a dangerous character. If a few drops of chloroform be evaporated from a blotting paper on the palm of the hand, no foreign odor should be detected.

Detection of Chloroform.—A very delicate test for chloroform, even in the presence of alcohol, is to add some solution of NaOH in alcohol and a little anilin to the suspected liquid. Either immediately or on gently warming the mixture, a strong odor of phenylisocyanide is produced.

Second test.—When heated with Fehling's solution, chloroform very promptly precipitates cuprous oxide. Alcohol does not interfere with the test.

Third test.—When chloroform is added to a solution of beta-naphthol in strong KOH solution, and the liquid heated to about 50° C. (122° F.), a fine Prussian-blue color is produced, changing gradually, on exposure to the air, to a green and finally to a brown. Chloral hydrate gives the same reaction. The boiling point of chloroform is a valuable indication of its purity. Pure chloroform boils at 60.8° C. (141.4° F.). The presence of one-half per cent. of alcohol reduces the boiling point to 59.8° C. (139.5° F.). A boiling point higher

than 61° C. (141.8° F.) indicates the presence of amyl or butyl compounds.

Spiritus chloroformi (U. S. P.) contains six per cent. by volume of chloroform and ninety four per cent. of alcohol.

Methyl-bromide, CH_3Br, or **monobrom-methane**, and **dibrom-methane** have little or no interest to the medical student.

Tribrom-methane, or **bromoform**, $CHBr_3$, closely resembles chloroform in properties. It boils at 150° C. (302° F.). It is not infrequently present in commercial bromine, even to the extent of ten per cent. It is prepared by gradually adding bromine to a cold solution of KOH in methyl-alcohol, until the liquid begins to be colored. It is rectified by treatment with $CaCl_2$ and redistillation. It is soluble in ether and alcohol, and but sparingly so in water.

Iodoform, tri-iodomethane, iodoformum (U. S. P., Br.), CHI_3, is formed by the combined action of KOH and iodine upon ethyl-alcohol. Its formation is a convenient test for ethyl-alcohol, or acetic aldehyde. This compound is prepared by acting upon common alcohol, aldehyde, acetone, and many other compounds with iodine, and potassium hydroxide or carbonate. Although made from ethyl-alcohol, it ought to be regarded as a derivative of CH_4 by substitution of I_3 for H_3.

It crystallizes in yellow scales, which, under the microscope, resemble the beautiful forms of snowflakes. It has a penetrating, saffron-like odor, melts at 120° C. (248° F.), and volatilizes slowly at ordinary temperatures. It is insoluble in water, but soluble in alcohol, ether, chloroform, bisulphide of carbon, and fixed and volatile oils. It is neutral in reaction, and volatilizes completely on heating it.

Physiological Effects.—Iodoform is a stimulant and anesthetic when applied to wounds, and is much prized by many surgeons as an antiseptic dressing for wounds after operations. It prevents putrefactive decompositions and acts as a deodorizer, but its own odor is disagreeable to many persons.

Tests for Impurities.—Commercial iodoform, on agitation with water, should not yield a liquid precipitable by $BaCl_2$ or $AgNO_3$. (Absence of sulphates and chlorides.) It should be wholly soluble in boiling alcohol, and should leave no residue on ignition in the air. Picric acid has been used as an adulterant of iodoform. It may be detected by agitating a sample with a dilute solution of NaOH or Na_2CO_3, carefully neutralizing the filtrate with acetic acid, and adding potassium nitrate, when a yellow precipitate of potassium picrate will be thrown down.

Haloid Substitution Products derived from Ethylic Alcohol.—These are formed by replacing the hydroxyl group by one of the halogen elements—viz., fluorine, chlorine, bromine, or iodine.

Ethyl-chloride, C_2H_5Cl, is prepared by passing gaseous HCl into a boiling solution of zinc chloride in twice its weight of alcohol.

$$C_2H_5OH + HCl = C_2H_5Cl + HOH.$$
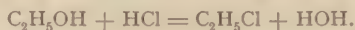
The ethyl-chloride distils over and is dissolved in alcohol. It is a colorless liquid of sp. gr. 0.92, boiling at 12.5° C. (54.0° F.). A mixture of C_2H_5Cl and methyl-ether is used as a local anesthetic.

Ethyl-bromide, C_2H_5Br, is prepared by the action of bromine and phosphorus on absolute alcohol. It is a colorless liquid, boiling at 39° C. (102° F.). It, as well as the chloride, has anesthetic properties. The bromide has been employed for this purpose, but is not considered free from danger.

ALCOHOLS.

The alcohols may be regarded as compounds composed of hydroxyl and a hydrocarbon radical ; or they may be regarded as the result of the substitution of OH for one or more H atoms in a hydrocarbon molecule. In fact, nearly all hydrocarbons may be so changed by the action of hydrogen dioxide. They may also be regarded as constructed on the water type. They may then be regarded as formed from a molecule of water, in which one of the hydrogen atoms has been replaced by a hydrocarbon radical—*i. e.*, they may be regarded as hydroxides of a hydrocarbon or alcohol radical, and they resemble in structure the bases of inorganic chemistry.

<div style="text-align:center">

H—O—H $HOCH_3$ HOC_2H_5
Water.   Methyl-alcohol.   Ethyl-alcohol.

</div>
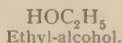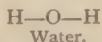
Alcohols are classified as **monatomic, diatomic, triatomic,** etc., according to the number of hydroxyl groups in the molecule. The hydrogen of the hydroxyl group, in alcohols, may be replaced by both positive and negative radicals. This H is called **alcoholic hydrogen**, to distinguish it from the other H atoms in the alcohol molecule.

A **monatomic** alcohol is one containing but one OH group.

A **diatomic** alcohol is one containing two OH groups.

A **triatomic** alcohol is one containing three OH groups.

Alcohols are also divided into **primary, secondary,** and **tertiary,** to distinguish the various isomers which exist among these bodies.

A **primary** alcohol is one in which the hydroxyl is attached to a carbon atom which is united to but one other carbon atom, as CH_3–CH_2–CH_2–O–H. They contain the group CH_2OH.

A **secondary alcohol, or iso-alcohol,** is one in which the

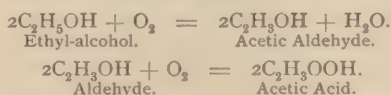hydroxyl group is attached to a carbon atom which is joined to two other carbon atoms, and contains the group CHOH instead of CH_2OH of the primary alcohols ; as, for example :

$$CH_3—CH—CH_3$$
$$|$$
$$O$$
$$|$$
$$H$$

Isopropyl-alcohol.
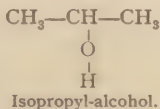
Or, it may be an alcohol derived from an isomeric hydrocarbon. Thus, from butane we may have two isomeric alcohols, according to the following formulæ :

$CH_3.CH_2.CH_2.CH_2OH$ and $CH_3 CH_2.CHOH.CH_3$.
Normal Butyl-alcohol.   Isobutyl-alcohol.

From isobutane we also have two isomeric alcohols, the one primary and the other tertiary :

CH_3
$>CHCH_2OH$ and CH_3
CH_3 $>COHCH_3$.
                                     CH_3
Isopropyl-carbinol,   Trimethyl-carbinol,
or   or
Primary Isobutyl-alcohol.   Tertiary Butyl-alcohol.
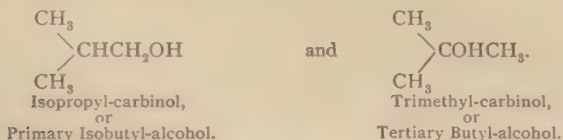
A **tertiary alcohol** is one in which the hydroxyl group is linked to a carbon atom which is joined to three other carbon atoms, and it contains the group COH ; for example :

$$CH_3$$
$$|$$
$$CH_3—C—CH_3$$
$$|$$
$$OH$$

Tertiary Butyl-alcohol, or Trimethyl-carbinol.
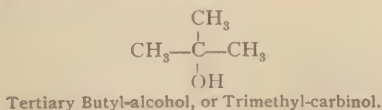
Greater facility in naming the alcohols may be attained by regarding them all as derivatives of methyl-alcohol, or **carbinol**. According to this view, the formulæ and corresponding names are as follows :

Carbinol, CH_3OH.
Ethyl-alcohol, or Methyl-carbinol, CH_3CH_2OH.
Propyl-alcohol, or Ethyl-carbinol, $C_2H_5—CH_2OH$.
Isopropyl-alcohol, or Dimethyl-carbinol, $CH_3—CHOH—CH_3$.
Isobutyl-alcohol, or Trimethyl-carbinol, $(CH_3)_3COH$.
Butyl alcohol, or Propyl-carbinol, $C_3H_7CH_2OH$.
Primary Isobutyl-alcohol, or Isopropyl-carbinol, $C_3H_9CH_2OH$.

The primary, secondary, and tertiary alcohols are distinguished by their behavior with oxidizing agents. Primary alcohols, when oxid-

ized, at first form an aldehyde, and, finally, an acid containing the same number of carbon atoms as itself.

$$2C_2H_5OH + O_2 = 2C_2H_3OH + H_2O.$$
Ethyl-alcohol.　　　Acetic Aldehyde.

$$2C_2H_3OH + O_2 = 2C_2H_3OOH.$$
Aldehyde.　　　Acetic Acid.

Secondary alcohols, when oxidized, yield a ketone having the same number of carbon atoms as itself, but no organic acid.

$$2(CH_3)_2CHOH + O_2 = 2(CH_3)_2CO + H_2O.$$
Isopropyl-alcohol, or　　　Dimethyl-ketone.
Dimethyl-carbinol.

A tertiary alcohol, when oxidized, is either broken up into two or more acids, or it may form a ketone having one carbon atom less than itself, while the other carbon atom forms formic or carbonic acid.

$$2(CH_3)_3COH + 3O_2 = 2(CH_3)_2CO + 2HCOOH + 2H_2O.$$
Trimethyl-carbinol.　　　Dimethyl-ketone. Formic Acid.
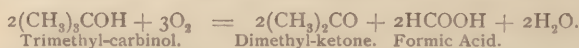
Monatomic Alcohols.—Having given a brief definition of the several groups of alcohols, we shall now proceed to notice briefly those members which may be considered of most importance to the student of medicine or pharmacy. We shall omit many of the compounds which are of chemical interest only.

TABLE OF MONATOMIC ALCOHOLS OF THE FIRST SERIES, WITH CORRESPONDING ACIDS.

ALCOHOLS.	FORMULA.	BOILING POINT.	FATTY ACIDS.	FORMULA.	BOILING POINT.
Methyl - alcohol (Wood-spirit), ...	CH_3-O-H	66° C.	Formic Acid,	$HCHO_2$ +	100° C.
Ethyl - alcohol (Spirit of Wine), ...	C_2H_5-O-H	78.4° C.	Acetic Acid,	$HC_2H_3O_2$	118° C.
Propyl-alcohol, ...	C_3H_7-O-H	97° C.	Propionic Acid,	$HC_3H_5O_2$	141° C.
Butyl-alcohol, ...	C_4H_9-O-H	116° C.	Butyric Acid,	$HC_4H_7O_2$	163° C.
Amyl- or Pentyl-alcohol, .	C_5H_{11}-O-H	137° C.	Valerianic or Pentylic Acid,	$HC_5H_9O_2$	185° C.
Hexyl-alcohol, ...	C_6H_{13}-O-H	157° C.	Caproic or Hexylic Acid,	$HC_6H_{11}O_2$	205° C.
Heptyl-alcohol, ...	C_7H_{15}-O-H	176° C.	Œnanthic or Heptylic Acid,	$HC_7H_{13}O_2$	224° C.
Octyl-alcohol, ...	C_8H_{17}-O-H	195° C.	Caprylic or Octylic Acid,	$HC_8H_{15}O_2$	233° C.
		Melting Point.			*Melting Point.*
Cetyl-alcohol, ...	$C_{16}H_{33}$-O-H	50° C.	Palmitic Acid,	$HC_{16}H_{31}O_2$	62° C.
			Stearic Acid,	$HC_{18}H_{35}O_2$	69.2° C.
Ceryl-alcohol, ...	$C_{27}H_{55}$-O-H	79° C.	Cerotic Acid,	$HC_{27}H_{53}O_2$	78° C.
Melissyl-alcohol, ...	$C_{30}H_{61}$-O-H	85° C.	Melyssic Acid,	$HC_{30}H_{59}O_2$	88° C.

Carbinol, Methyl-alcohol (Wood-spirit).—CH_3OH. Methyl-alcohol occurs among the products of the destructive distillation of wood, forming about one per cent. of the distillate.   The alcohol is separated from the other products by careful fractional distillation. It is then redistilled after adding lime.   This is then treated with dry calcium chloride, with which the alcohol combines to form a solid, crystalline body, from which other impurities may easily be separated ; the alcohol is recovered from this solid by distilling with water.   The water is finally removed by treating with quicklime and distilling at a low temperature.   Oil of wintergreen consists chiefly of the methyl-ether of salicylic acid.   On distilling this oil with potassium hydroxide, pure methyl-alcohol is obtained.

Methyl-alcohol is a transparent, colorless, mobile liquid, having a spirituous odor and a sp. gr. of 0.8142.   It burns with a bluish flame. It is miscible with water in all proportions.   By oxidation it yields formic acid.

$$CH_3OH + O_2 = CHO_2H + H_2O.$$
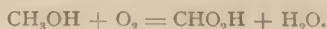
With acids it produces ethers.   With acetic acid it gives methyl-acetic ether, or methyl-acetate, CH_3—O—C_2H_3O. With hydrochloric acid it gives methyl-chloride, CH_3Cl.   Many other ethers and substitution products are known.   The **physiological action** of methyl-alcohol is similar to that of common ethyl-alcohol, but more transient.

Methylated spirit is a mixture of ninety parts of common alcohol and ten parts of methyl-alcohol.

Ethyl-alcohol, Common Alcohol.—C_2H_5OH.   It is prepared from saccharine liquids by the growth of a microscopic plant called yeast, or ferment.   The process is called fermentation.   Cane-sugar, starch, and cellulose can be fermented only after conversion into glucose or levulose, which can be slowly accomplished by the yeast itself.

$$C_{12}H_{22}O_{11} + H_2O = \underset{\text{Glucose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}.$$

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_6O + 2CO_2.$$
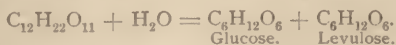
This reaction accounts for only ninety-four to ninety-six per cent. of the sugar employed, the remaining part being transformed into other products, such as succinic acid, glycerin, "fusel oil," etc.   The organisms under whose influence this change takes place are several varieties of *Saccharomyces*, or yeast-plants.   The sugar to be fermented may be from the juices of fruits or sugar-cane, or it may be previously prepared from the starch of the cereals by the aid of malt or sulphuric acid.   The secondary or side-products in the fermentation vary somewhat with sugars from these various sources, and thus give rise to the

different flavors of the fermented liquors. The alcohol may be sepa-
rated from the water and other products after the fermentation by
careful fractional distillation. If it be desired to prepare an alcohol
containing more than ninety per cent., some substance must be added
which will combine with and hold back the water,—as quicklime, an-
hydrous copper sulphate, potassium carbonate, or barium hydroxide,
—after which it is again distilled.

Absolute alcohol, alcohol absolutum (U. S. P.), **alcohol
ethylicum** (Br.), is a colorless, limpid liquid of an agreeable odor and
burning taste. It attracts water, and mixes slowly with this liquid in
all proportions, with the production of heat and contraction in volume.
It boils at 78.4° C. (173° F.), and solidifies at 130.5° C. (202.9°
F.). It is neutral to test-paper, and burns readily, with a non-luminous
flame. It dissolves resins, essential oils, alkaline hydroxides, calcium
chloride, and a large number of organic bodies. Oxidizing agents
convert it into aldehyde and, finally, into acetic acid. Nitric acid
(fuming) decomposes it very rapidly, giving a number of acids and
ethers. If ninety per cent. of alcohol is added to a solution of mer-
cury or silver in nitric acid, a rapid ebullition takes place, forming a
crystalline deposit of **fulminate of silver** or **mercury,** which
explodes, when dry, by percussion, and is used in filling percussion
caps. The formulæ are $C_2N_2O_2Ag_2$ and $C_2N_2O_2Hg$. The alkaline
metals attack alcohol, and give ethylates of these metals.

$$2C_2H_5OH + K_2 = 2C_2H_5OK + H_2.$$
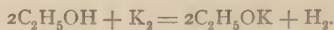
When distilled with sulphuric acid and a salt of an organic acid, it
forms compound ethers.

Physiological Action.—Alcohol, when concentrated, is a poison.
Even when taken in large doses, well diluted, it has frequently caused
death, probably by paralysis of the muscles of respiration or of the
heart. In full doses it causes a feeling of warmth in the stomach, fol-
lowed by congestion of this organ. After absorption, there is at first
a feeling of exhilaration, with exalted animal functions, quickened
pulse, and increased circulation, with dilatation of the superficial
blood-vessels. This is often accompanied and always followed by in-
coherence of ideas and muscular actions, and finally a general weak-
ness of all the voluntary actions. The temperature is lowered, both
in health and in most diseased conditions. The prolonged use of
alcoholic beverages is characterized by general degenerative changes,
either fatty or fibroid. There are no conclusive arguments to prove
the benefit to be derived from the use of alcohol in health, but in cer-
tain diseased conditions it is of undoubted value.

Commercial Forms.—Commercial alcohol varies in strength

from 85 to 95 per cent. **Alcohol deodoratum** (U. S. P.) contains about 92.5 per cent. by weight, and 95.1 per cent. by volume, of ethyl-alcohol. It is purer and stronger than the ordinary alcohol, which contains about 91 per cent. by weight, or 94 per cent. by volume, of alcohol, and about 9 per cent. by weight of water.

Deodorized alcohol should have a sp. gr. of about 0.816 at 15° C. (59° F.), and when mixed with an equal volume of water and one-fifth volume of glycerin, and the mixture allowed to evaporate spontaneously from clean blotting-paper, it should leave no foreign odor. It should not turn brown upon adding to it concentrated sulphuric acid.

Alcohol dilutum contains 41 per cent. by weight, or 48.6 per cent. by volume.

Proof spirit, spiritus tenuior (Br.), contains 49 per cent. C_2H_6O ; so called because it is the weakest alcohol that will fire gun-powder.

Tinctures are solutions of medicinal, non-volatile, or only partially volatile, substances in liquids other than glycerin or water. Solutions of volatile substances in water are known as **medicated waters,** and similar solutions in alcohol as **spirits.** The liquids employed in the preparation of tinctures are alcohol of different strengths, spirit of ether, spirit of nitrous ether, mixtures of water, alcohol, and glycerin, and aromatic spirit of ammonia or ammoniated alcohol. According to the liquid employed, tinctures are known as ammoniated, ethereal, or alcoholic. The greatest number of tinctures are made with alcohol. Most tinctures of the U. S. P. are prepared with diluted alcohol ; those of the Br. P. with proof spirit. The U. S. P. official tinctures, of which there are seventy-two, are made in three ways : (1) by percolation ; (2) by maceration ; (3) by solution or dilution.

Preparation of Tinctures.—Tinctures of resins, oleoresins, balsams, and most of the gum-resins are best prepared by maceration. All other drugs are conveniently extracted by percolation. This plan has been generally adopted by the U. S. P. where practicable. The Br. P. directs first to macerate the drug for forty-eight hours and then to percolate. The Ger. P. directs to prepare all tinctures by maceration or digestion.

Detection and Estimation of Alcohol.—Alcohol may be detected in quantities of one per cent. or more, in any fluid, by shaking the sample for a few minutes with a small quantity of powdered guaiacum taken from the center of a lump. Filter the liquid and add a few drops of diluted hydrocyanic acid and a drop of a weak solution of $CuSO_4$. If alcohol be present, a blue color is produced, which can best be seen by holding the tube over white paper.

Second test.—A very delicate test for alcohol depends on the fact that alcohol, under the influence of iodine and an alkali, yields iodoform, CHI_3. To 10 c.c. of the liquid add 5 drops of a 10 per cent. solution of NaOH, and warm to about 50° C. (122° F.). A saturated solution of iodine in a solution of KI is next added, drop by drop, until the liquid becomes slightly yellow. If alcohol be present, iodoform is gradually deposited in yellow crystals, which may be examined with a lens.

Third test.—A solution of one part of molybdic acid in ten of strong H_2SO_4, when warmed with the suspected solution, immediately gives a blue color in the presence of alcohol, ether, or aldehyde. It will detect 0.1 per cent.

Alcohol is estimated quantitatively in mixtures with water by means of its sp. gr. and reference to an alcoholic table prepared for the purpose. In tinctures, wine, beer, or other beverages, 100 c.c. of the sample is put into a retort and distilled until about one-half distils over. The distillate is collected and pure water added to make the volume up to that of the beverage taken It remains then to take the sp. gr. of this solution, and refer to the table to determine the percentage of alcohol. The sp. gr. in these cases must be taken with extreme care, with the sp. gr. bottle.

Alcoholic beverages are usually of three classes—viz., **distilled, fermented,** and **malt liquors.** To the first class belong **spirits** distilled from fermented liquors—**brandy** from wine, **whisky** from a mash of corn or rye, **rum** from molasses, **gin** from corn-spirit mixed with juniper berries.

To the second class belong the various wines. To the third class belongs **beer,** prepared from malted barley and hops. **Ale, porter,** and **stout** differ from beer only in the selection and proportion of the malt, hops, and flavoring materials.

We introduce here some results of the analyses of various distilled liquors, as found in the American market, for the purpose of comparison as to the ordinary strength of alcohol (" N. Y. State Board of Health Report," 1882):

	BRANDY.	WHISKY.	RUM.
Specific gravity,	0.9297 to 0.9615	0.9018 to 0.9646	0.9126 to 0.9684
	PER CENT.	PER CENT.	PER CENT.
Alcohol, { By volume, 30.80 to 50.40		28.90 to 60.30	26.40 to 50.30
{ By weight, 25.39 to 42.96		23.75 to 52.58	21.66 to 42.87

It seems, therefore, that there is a great variation in the strength of these liquors as ordinarily sold; while they are supposed to contain from 40 to 50 per cent. of alcohol by volume, in reality they usually contain from 35 to 45 per cent. It is, therefore, a very uncertain way of prescribing alcohol, to prescribe any one of these beverages. A much more certain method is to prescribe alcohol of known strength, flavored with ethereal essences, and softened with glycerin or syrup.

Wines contain from 6 to 25 per cent. of alcohol.

Port Wine, ... 16.62 to 23.2 per cent.
Sherry " . . . . 16.00 to 25.0 "
Bordeaux, Red, ... 6.85 to 13.0 "
    " White, ... 11.00 to 18.0 "
Champagne, ... 5.80 to 13.0 "

COMPOSITION OF FORTIFIED WINES. (DUPRE.)

	SHERRY.	MADEIRA.	MARSALA.	PORT.
Sp. gr., ...	0.9979	0.9939	0.9966	0.9974
Alcohol, ...	17.20	17.75	16.71	17.53
Extract, ...	5.38	4.35	4.98	5.39
Glucose, ...	2.97	2.08	3.24	2.28
Mineral matters, ...	0.55	0.39	0.22	0.26
Acidity (as tartaric acid), ...	0.52	0.54	0.33	0.49
Phosphoric acid, ...	0.025	0.042	0.018	0.033

The following table is taken from Fresenius and Borgmann, and shows the average composition of certain pure wines in grams per 100 C.C. :

	RED MAIN.	WHITE MAIN.	HOCKS.	WHITE FRENCH.	RED FRENCH.	MOSELLE.
Alcohol—						
Maximum, . . .	9.51	10.15	10.39	9.84	9.32	8.72
Minimum, . . .	9.49	8.90	6.42	9.05	7.99	7.04
Average, ...	9.50	9.52	8.77	9.44	8.56	8.08
Extract, ...	3.00	2.43	2.32	2.54	2.44	2.11
Mineral matters, . .	0.32	0.19	0.22	0.26	0.25	0.18
Acidity, ...	0.58	0.69	0.62	0.62	0.54	0.79
Glycerin, ...	1.19	1.10	0.92	0.94	0.86	0.73
Sulphuric acid, SO_3, .	0.076	0.044	0.047	0.017	0.013	0.012
Phosphoric acid, P_2O_5,	0.065	0.039	0.040	0.034	0.027	0.047

Beers and porters contain from 1 to 10 per cent. of alcohol; average, about 4 to 5 per cent. by volume. The average of extractive matters (dextrin, cellulose, sugar, lupulin, and hop-resin) is 4 to 15 in ale, 4 to 9 in porter, and about 5 per cent. in beer. All alcoholic beverages are subject to gross adulterations. Artificial beverages are frequently sold in all markets.

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The following table gives the average composition of malt liquors (Allen) :

	SP. GR.	ALCO-HOL.	SOLID MATTER OR EXTRACT.	FREE ACID.	ASH.
Pilsen Lager, ...	1.013	3.55	5.15	. . .	0.20
Hanoverian Lager (average of 20 samples), ...	1.017	4.01	6.34	. . .	0.24
American Lager (average of 19 samples), ...	1.016.2	2.78	6.05	0.12	0.30
Bass's Pale Ale, ...	1.013.8	6.25	6.98	0.14	. . .
Alsop's Pale Ale, ...	1.014.4	6.37	4.44	0.24	. . .
Guiness's Stout, ...	. . . .	6.66	7.24	0.20	. . .
" "	1.124.4	5.05	5.48	0.23	. . .
Dublin "	. . . .	5.50	8.71	0.18	. . .
Munich Lager, ...	1.021	4.75	7.08	0.15	. . .

Propyl-alcohol, or **ethyl-carbinol,** C_3H_7OH, is found in the later portions of the distillate in rectifying crude alcohol. Its sp. gr. is 0.82. It boils at 97.5° C. (207.5° F.). It may be separated from its mixture with water by saturating it with $CaCl_2$, which absorbs the water and allows the alcohol to separate as a layer. When oxidized, it yields **propyl-aldehyde,** C_3H_5OH, and **propylic acid,** C_2H_5COOH.

Butyl-alcohol.—C_4H_9OH. There are four butyl-alcohols known. The butyl-alcohol of fermentation is formed in small quantities during the alcoholic fermentation of sugars. It may be obtained by repeated fractional distillation of the heavier portions that come over at the end of the distillation of the mash. It is a colorless liquid, boiling at 116° C. (240.8° F.). It is more poisonous than ethyl- or methyl-alcohol.

Amyl-alcohol, Fusel Oil, * **Potato-spirit, Isobutyl-carbinol.** —$C_5H_{11}OH$. Of the eight possible theoretical amylic alcohols, seven are known :

Normal Amyl-alcohol, or Primary Amylic Alcohol.

Isobutyl-carbinol, or Iso-amylic Alcohol.
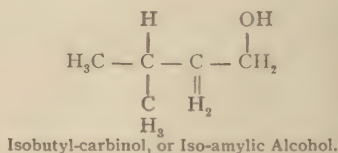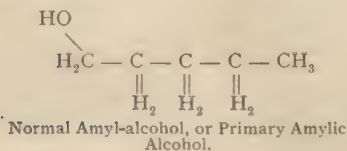
* Fusel oil, properly speaking, is a mixture of several alcohols, of which amyl-alcohol is one.

$$HO — \underset{\underset{\underset{CH_3}{|}}{\underset{CH_2}{|}}}{\overset{\overset{H}{|}}{C}} — CH_2—CH_3$$

Di-ethyl Carbinol.

$$HO \quad H_2 \quad H_2$$
$$H\overset{|}{C} — \overset{||}{C} — \overset{||}{C} — CH_3$$
$$\underset{CH_3}{|}$$
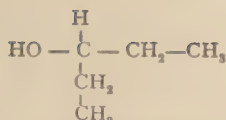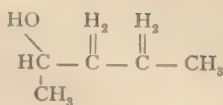
Methyl-propyl Carbinol.

$$CH_3 — \underset{\underset{CH_3}{|}}{\overset{\overset{HO}{\diagdown}}{C}} — \overset{\overset{H_2}{||}}{C}—CH_3$$
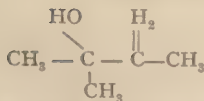
Dimethyl-ethyl Carbinol, Tertiary Amylic
Alcohol, or Amylene Hydrate.

$$H_3C — \overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}} — \overset{\overset{CH_2OH}{|}}{\underset{\underset{H}{|}}{C}} — CH_3$$
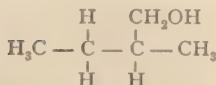
Secondary Butyl-carbinol.

$$H_3C — \overset{\overset{O—H}{|}}{\underset{\underset{H}{|}}{C}} — \underset{\underset{H}{|}}{C}\overset{\diagup CH_3}{\diagdown CH_3}$$
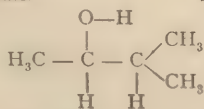
Methyl-isopropyl Carbinol.

Of these compounds the only ones of interest are isobutyl-carbinol and amylene hydrate.

Amyl-alcohol, isobutyl-carbinol, alcohol amylicum (Br.), $C_5H_{11}OH$. is formed in small quantities at the same time with ethyl-alcohol, during the fermentation of barley-, corn-, and especially potato-mash. It is prepared from the residue left in the still after the common alcohol has been distilled off. The product coming over at 132° C. (269° F.) is that collected.

It is a colorless, oily liquid, possessing a peculiar, irritating odor, which excites coughing, and a burning taste. It is not miscible with water, but mixes in all proportions with alcohol and ether. It is a good solvent of certain alkaloids. Taken internally, both in the form of vapor and when taken by the stomach, it acts as a poison, producing dizziness, headache, and intoxication. Much of the unwholesomeness of imperfectly rectified spirituous liquors arises from their contamination with fusel oil.

The principal uses of fusel oil are in the preparation of varnish, and as a source of amyl-ethers, which are used extensively to prepare artificial flavoring extracts. Thus, the acetate has the odor of pears, and is used by confectioners under the name of "**pear oil**," while the valerianate is used to give the flavor of apples, and is called "**apple oil**."

Amylene Hydrate, or Dimethyl-ethyl-carbinol.—CH_3—CH_2—$COH = (CH_3)_2$. When amyl-alcohol is heated with $ZnCl_2$, amylene, C_5H_{10}. is formed ; this combines with hydriodic acid to form amylene iodide. This iodide, when treated with Ag_2O, gives tertiary amylic alcohol, or amylene hydrate. This is a colorless

liquid, boiling at 108° C. (226.4° F.), with a peculiar odor resembling menthol. It is soluble in eight parts of water and freely soluble in alcohol. It has been employed, in doses of twenty to twenty-five grains, as a hypnotic.

Among the higher monatomic alcohols the following are of interest :

Cetyl-alcohol, $C_{16}H_{33}OH$, formerly termed **ethal,** is obtained by saponifying spermaceti (cetaceum, U. S. P.), which consists of palmitate of cetyl. Spermaceti is a solid, crystallized fat accompanying sperm-oil, in the head of the sperm-whale.

Ceryl-alcohol, $C_{27}H_{55}OH$, is obtained in the same manner from Chinese wax.

Melissyl-alcohol, $C_{30}H_{61}OH$, is obtained from that portion of beeswax soluble in alcohol, which is composed of melissyl-palmitate. Yellow wax (cera flava, U. S. P.) and white wax, which is bleached by exposure to moisture, air, and sunlight, are prepared from the honey-comb. Beeswax contains, besides melissyl-palmitate, cerotic acid and cerolein. The adulterants found in wax are paraffin and ceresin. Both paraffin and ceresin reduce the melting point of wax, which should not be lower than 63.3° C. (146° F.). Pure wax will yield not more than three per cent. to cold alcohol, whereas resin, if present, would be extracted by the alcohol. Both paraffin and ceresin are insoluble in alcohol.

Diatomic alcohols (glycols) are of little interest to the physician or pharmacist. They may be regarded as being derived from two molecules of water, in which one atom of H from each molecule has been replaced by a diatomic radical.

Glycol, $C_2H_4(OH)_2$, or **ethylene alcohol,** is a colorless, transparent, almost odorless liquid, less mobile than alcohol, having a sweetish taste, and boiling at 197° C. (386.6° F.). It mixes with water and in alcohol in all proportions. It is prepared by decomposing ethylene dibromide with potassium carbonate.

$$C_2H_4Br_2 + K_2CO_3 + H_2O = C_2H_4(OH)_2 + 2KBr + CO_2.$$
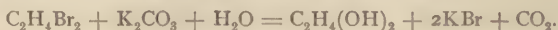
It has no practical applications in medicine.

TRIATOMIC ALCOHOLS, OR GLYCERINS.

Glycerin, glycerol, glycerinum (U. S. P., Br.), $C_3H_5\begin{cases} OH \\ OH, \\ OH \end{cases}$ was

discovered by Scheele in 1779, and was called by him **the sweet principle of oils.** It is prepared on a large scale from the neutral fats, as

a side-product in the manufacture of soap and candles. These fatty bodies are composed of fatty acids in combination with glyceryl, C_3H_5, the radical of glycerin—*i. e.*, they are compound ethers of the fatty acids and glyceryl. On treating these ethers with alkalies, a salt of the alkali with the acid is formed, termed a soap ; the glyceryl is set free by the reaction and remains dissolved in the water present. This process of decomposing a compound ether into an alcohol and acid, or salt of the acid, is called **saponification**. Neutral fats can also be saponified by treating them with superheated steam, which is the process now usually employed in candle factories. The glycerin is freed from the water by evaporation, and finally by distillation with the aid of superheated steam. Glycerin is also formed during alcoholic fermentation, and is found in wines, etc. It is a colorless, syrupy liquid, possessing a sweetish taste and no odor. Its density is 1.28 at 15.5° C. (60° F.). The official **glycerinum** has a density of 1.25. It is soluble in all proportions in water and alcohol, but not in ether. It is hygroscopic, and absorbs water readily until it has absorbed twice its own volume. Its range of solubility is large, as will be seen by the table in the appendix. When heated in air, it boils at 290° C. (554° F.), and distils with partial decomposition. At low temperatures, it forms, under certain circumstances, a crystalline mass. When heated in the air to a high temperature, it takes fire and burns, leaving no residue. Boric acid imparts a green color to its flame, or to a flame directed upon a platinum wire moistened with it. This is one of the most convenient tests for boric acid. Chemically, glycerin is, as above stated, a triatomic alcohol—*i. e.*, it contains three hydroxyl groups. When oxidized, it yields glyceric acid,

$$C_3H_3 \begin{cases} O.OH. \\ OH. \\ OH. \end{cases}$$ It is capable, in certain circumstances, of undergoing

fermentation with yeast, producing ethyl-alcohol, propyl-alcohol, butyric and caproic acids. It unites with the alkalies and alkaline earths, the compounds being soluble in water. It prevents the precipitation of copper hydroxide by sodium or potassium hydroxide, and has been recommended for this purpose in the preparation of Fehling's test solution for glucose.

Glycerin is sometimes adulterated with glucose, cane-sugar syrup, and water. The first of these will usually be easily detected by adding a solution of sodium hydroxide (caustic soda) and enough copper sulphate to impart a blue color, and boiling for a few minutes, when, if glucose be present, red cuprous oxide will be precipitated. The presence of water may be detected by taking the specific gravity, which should not be below 1.25. Glycerin is the basis of

the manufacture of nitroglycerin, used in various forms of blasting agents, such as "dualine," "dynamite," "giant powder," "rend-rock," etc., which are usually composed of nitroglycerin and some porous substance in powder form.

When glycerin is saturated with gaseous HCl, and then heated for several hours to 100° C., **monochlor-** and **dichlorhydrines** are formed.

$$C_3H_5(OH)_3 + HCl = C_3H_5(OH)_2Cl + H_2O.$$
$$C_3H_5(OH)_3 + 2HCl = C_3H_5OHCl_2 + 2H_2O.$$
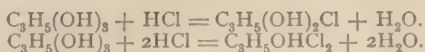
Sulphuric acid combines with glycerin to form **glycerosulphuric acid.** Glacial or metaphosphoric acid forms **glycerophosphoric acid.**

$$C_3H_5(OH_2)_2OPO_3H_2.$$
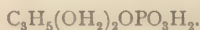
This acid is one of the decomposition products of lecithin and protagon, two complex bodies found in nerve-substance, especially of the brain. The acid itself has been found in the brain, nerves, muscles, yolk of egg, bile, and pus. The phosphorus present in nerve-tissue probably exists in the form of either lecithin or protagon, both of which contain glycerophosphoric acid. The esters of glycerin and organic acids will be referred to later. (See Neutral Fats.)

Nitroglycerin, or Glyceryl Trinitrate.—$C_3H_5 \begin{cases} NO_3. \\ NO_3. \\ NO_3. \end{cases}$ When

glycerin is allowed to flow in a slow stream into a mixture of strong nitric and sulphuric acids, kept cold by a freezing mixture, and the mixture afterward thrown into a large quantity of cold water, there separates out a heavy, colorless, poisonous, oily liquid—nitroglycerin. It crystallizes at —20° C. (—4° F.); sp. gr., 1.6. When inflamed in the air, it burns quietly and rapidly; but when ignited by percussion or quick heating, especially in a confined space, it explodes with terrific violence, and hence is much used in blasting. In order to make this explosive agent less dangerous to handle, it is usually mixed with some inert powder, such as clay, diatomaceous earth, sawdust, etc., and is then sold under the name of dynamite, dualine, rend-rock, and giant powder. Under the name of **spiritus glonoini**, a one per cent. alcoholic solution is official, and is used as a heart-stimulant.

Tetratomic Alcohols.—The only one of this class of alcohols of sufficient importance to be mentioned here is **erithrite** or **phy-cite,** $C_4H_6(OH)_4$. It occurs in many lichens and algæ in combination with orsellic acid, as **erythrin.**

Pentatomic alcohols have not been found in nature, but several have been prepared by the reduction of certain pentoses. They are of scientific interest only.

HEXATOMIC ALCOHOLS.

In the hexatomic alcohols the six hydroxyl radicals are united to six different carbon atoms, so that there must be six carbon atoms in the nucleus. This class of alcohols include :

Mannitol,	$C_6H_8(OH)_6$.
Dulcitol,	$C_6H_8(OH)_6$.
Sorbitol,	$C_6H_8(OH_6)$.
Rhamno-hexitol,	$C_7H_{10}(OH)_6$.

Mannitol, Mannite.—This is the sweet principle of manna, and is found widely distributed in the vegetable kingdom. It occurs in celery, fungi, and seaweeds, in the sap of the larch, the exuded sap of the apple, cherry, lime, etc., and the exuded sap of *Fraxinus ornus*, which in the dried state forms commercial manna. It may be prepared artificially by acting upon grape-sugar with sodium amalgam (nascent hydrogen), or by the so-called mucous and the butyric fermentations of sugar.

To obtain it from manna, dissolve it in half its weight of boiling water, add some albumen to clarify, and filter through cloth. On cooling, the mannite separates out. It may also be obtained pure by extracting manna with hot alcohol and crystallizing. It forms fine, silky needles when crystallized from alcohol, but large, transparent, rhombic prisms from the aqueous solution. Mannitol is intensely sweet, sparingly soluble in cold, readily soluble in hot water and alcohol, and insoluble in ether. It can readily undergo lactic and butyric fermentations, but not alcoholic. It combines with many metallic oxides, and also forms a large number of compound ethers.

Mild oxidation in presence of platinum-black produces **mannose,** $C_6H_7O(OH)_5$, the aldehyde of mannitol. By further oxidation it forms **mannonic acid,** $C_5H_6(OH)_5CO.OH$, and **manosaccharic acid,**

$$C_4H_4(OH)_4 \begin{cases} CO.OH. \\ CO.OH. \end{cases}$$
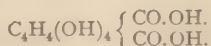
Dulcitol, Dulcite.—This isomeride of mannitol is found in **dulcose,** or dulcite manna, a crystalline substance from Madagascar. It is found in several plants. It has been prepared from milk-sugar, by treatment with sodium amalgam. The properties of dulcitol resemble those of mannitol.

Sorbitol, sorbite, is a third isomeride of mannitol found in mountain-ash berries and in the plum, cherry, apple, and pear. It forms small, colorless needles. It has been prepared synthetically

from dextrose. **Rhamnohexitol** has been prepared from rhamno-hexose, $C_7H_{14}O_6$.

Several of the sugars are oxidation products of these hexatomic alcohols. The relations of these alcohols to the sugars and acids are as follows:

ALCOHOL.	ALDEHYDE.	MONOBASIC ACID.	DIBASIC ACID.
Mannitol,	Mannose,	Mannonic Acid,	Manosaccharic Acid.
Dulcitol,	Galactose,	Galactonic Acid,	Mucic Acid.
Sorbitol,	Dextrose,	Gluconic Acid,	Saccharic Acid.

Levulose is the ketone of mannitol.

THE CARBOHYDRATES, OR SACCHARIDS.

Closely allied to the hexatomic alcohols is a class of important bodies found widely distributed in the vegetable kingdom, known as the carbohydrates. They contain, along with carbon, oxygen and hydrogen in the proportion to form water. Until very recently, this class of bodies were all believed to be natural bodies, formed by plant or animal life. Some of them have recently been formed by syn-thesis, and it now seems likely that at no distant day all of these important food-stuffs may be artificially prepared. Owing to the dis-covery of a considerable number of new compounds of this class, the old classification into **saccharoses, glucoses,** and **amyloses** has become insufficient. The number of carbon atoms entering into the molecule, instead of being six or a multiple of six atoms, is now known to vary from three to nine. They may be classified into **monosaccharids, disaccharids, trisaccharids,** and **polysac-charids.** A **monosaccharid** is a carbohydrate that, when digested with dilute acids, does not yield any other sugar or sugars. They are therefore the simplest of the sugars. A **disaccharid** is a carbo-hydrate or saccharid that, when digested with a dilute acid, does yield some other sugar, or yields two different sugars. A **trisaccharid molecule,** under similar conditions, splits up into three sugars, or, at least, into three sugar molecules.

The members of each of these classes are divided into smaller groups, designating the number of carbon atoms contained in their molecules, into **trioses, tetroses, pentoses, hexoses, heptoses, octoses,** and **nonoses,** according as they contain three, four, five, six, seven, eight, or nine atoms of carbon, respectively, in their molecules.

CLASS I.—MONOSACCHARIDS.

Trioses.—Glycerose, $C_3H_6O_3$. Formed by the oxidation of glycerin.
Tetroses.—Erythrose, $C_4H_8O_4$. Formed by the oxidation of erythrite.
Pentoses.—Aribinose, $C_5H_{10}O_5$; xylose, $C_5H_{10}O_5$; ribose, $C_5H_{10}O_5$; **rhamnose** or **isodulcite,** $C_5H_9(CH_3)O_5$; **fucose,** $C_5H_9(CH)_3O_5$.

Hexoses.—In this group are two subgroups—the aldehydes, or **aldoses**, and the ketones, or **ketoses**.

The **aldoses** include :

　　Dextrose, $C_6H_{12}O_6$, starch-sugar, or glucose.
　　Mannose, $C_6H_{12}O_6$, obtained from manna.
　　Gulose, a synthetic sugar.
　　Galactose, from inversion of lactose.
　　Talose, a synthetic sugar.
　　Rhamnohexose, $C_6H_{11}(CH_3)O_6$, a synthetic sugar.

The **ketoses** include :

　　Levulose, or **fructose**, from invert sugar.
　　Acrose, a synthetic sugar.
　　Sorbinose, from mountain-ash berries.

Heptoses.—**Manno-heptose**, $C_7H_{14}O_7$, obtained from mannose.
　　Gluco-heptose, $C_7H_{14}O_7$, obtained from glucose.
Octoses.—**Manno-octose**, $C_8H_{16}O_8$, prepared from mannose.
　　Gluco-octose, $C_8H_{16}O_8$, prepared from glucose.
Nonoses.—**Manno-nonose**, $C_9H_{18}O_9$, prepared from mannose.
　　Gluco-nonose, $C_9H_{18}O_9$, prepared from glucose.

CLASS II.—DISACCHARIDS.

Tribioses, $C_6H_{10}O_5$, and **tetrabioses**, $C_8H_{14}O_7$, are unknown.
Pentabioses, $C_{10}H_{18}O_9$.—**Arabinose**.
Hexabioses, $C_{12}H_{22}O_{11}$.—**Sucrose, lactose, maltose, isomaltose, trehalose** (mycose), **melabiose** (eucalyn), **turanose**.

CLASS III.—TRISACCHARIDS.

Hexatrioses.—**Raffinose**, or meletriose, $C_{18}H_{32}O_{16}$.
　　Melezitose, $C_{18}H_{32}O_{16}$.

CLASS IV.—POLYSACCHARIDS.

Under this class are grouped a number of carbohydrates of vegetable origin whose molecular formulæ have not been determined. Some of them are crystallizable, as **gentianose**, found in gentian root, and **lactosin** found in soap-bark, while others are non-crystallizable. To this latter group belong the **starches**, the **dextrins**, and the **celluloses**.

MONOSACCHARIDS.

These compounds are neutral, colorless, odorless, and sweet-tasting bodies, easily soluble in water, insoluble in ether, and soluble with difficulty in alcohol.

Being either aldehydes or ketones, they are easily oxidized, and therefore their alkaline solutions readily reduce certain metallic salts. The most characteristic reduction is afforded by the copper salts, and a solution of copper tartrate in sodium or potassium hydroxide, known

as **Fehling's solution**, is used as a test-fluid for this class of bodies. Many of them reduce the acetate of copper in a slightly acidulated acetic acid solution, known as **Barfoed's reagent**. The trioses, hexoses, and nonoses readily undergo alcoholic fermentation, while the pentoses, heptoses, and octoses do not.

All the monosaccharids give characteristic crystalline precipitates, with phenyl-hydrazin, $C_6H_5NH.NH_2$, known as **osazones**, when their solutions, slightly acidified with acetic acid, are heated with it. By this means they may be separated from the other classes and from one another, and may be identified. A number of these compounds are optically active, and may be estimated by the polariscope.

The **trioses** and **tetroses** are not of sufficient importance to merit here more than a mere mention.

The Pentoses.—The **pentoses** are sugars having the formula $C_5H_{10}O_5$, found in many plants and animals, and occasionally in the urine. A pentose has been obtained as a decomposition product of nuclein from pancreas and from yeast. The use of certain fruits, such as pears, which contain **pentosanes**, is followed by the appearance of pentose in the urine. The pentoses, when distilled with dilute hydrochloric acid, yield **furfurol**, C_4H_3OCHO, which gives a deep red color with phloroglucinol. This reaction is used to detect them. The pentoses reduce Fehling's solution, but do not ferment with yeast. The pentoses are not assimilable, and when foods containing xylose or arabinose, or beer, are taken, pentoses appear in the urine, and may be mistaken for dextrose.

The principal pentoses are : **arabinose**, $CH_2OH(CHOH)_3CHO$, prepared by boiling gum arabic and some other gums with dilute H_2SO_4; **xylose**, from wood-gum, straw, and jute ; **ribose, rhamnose,** and **fucose.**

The **trisaccharids** are not of sufficient importance to merit a separate description.

THE HEXOSES, OR GLUCOSES.

The hexoses are either aldehydes or ketones of the hexatomic alcohols ; hence, are oxidation products of these alcohols. The relation of these compounds has been given under the hexatomic alcohols. There are two groups of the hexoses ; the one consists of aldehydes and the other of ketones. The aldehydes are called **aldoses** and the ketones are called **ketoses.** By treatment with nascent hydrogen, the aldoses and ketoses are converted into the corre-

sponding hexatomic alcohols. The following graphic formulæ show the relation between the alcohols and these sugars:
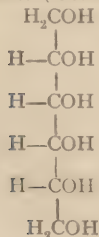
Mannitol (Alcohol).	Dextrose (Aldehyde).	Levulose (Ketone).
H_2COH	$O=C—H$	H_2COH
$H—COH$	$HCOH$	$O=C$
$H—COH$	$HCOH$	$HCOH$
$H—COH$	$HCOH$	$HCOH$
$H—COH$	$HCOH$	$HCOH$
H_2COH	H_2COH	$H_2COH.$
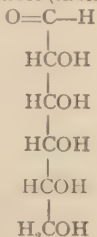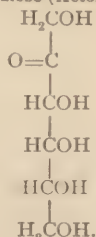
THE ALDEHYDE GROUP.

Dextrose, Glucose, Grape-sugar.—$C_6H_{12}O_6$. This sugar is widely diffused through the vegetable kingdom, occurring in grapes, honey, in most sweet fruits, sprouting grains, etc., usually mixed with an equal amount of levulose. It occurs in small quantity in the blood, yolk of eggs, and in larger quantity in diabetic urine. It is manufactured on a large scale from corn-starch, by boiling with dilute sulphuric acid, neutralizing with lime, drawing off the clear syrup after settling, and evaporating it down to a thick syrup and allowing it to crystallize. Dextrose is less sweet than cane-sugar, $2\frac{1}{2}$ parts of the former giving the sweetening power of 1 part of the latter. It is sometimes used to adulterate the light brown varieties of cane-sugar. When present in considerable quantity (five per cent.), it may often be detected by its property of mashing between the teeth instead of crushing like cane-sugar. Dextrose crystallizes with some difficulty, and, as usually met with in the market, it does not present to the naked eye a distinct crystalline appearance. It easily undergoes oxidation, especially in alkaline solutions, and thus acts as a reducing agent.

It readily reduces silver, copper, bismuth, and mercury salts in hot alkaline solutions. Silver, if ammonia be present, is reduced to the metallic state and deposited as a brilliant mirror on the surface of the vessel in which it is heated.

The ordinary methods of detection and estimation of dextrose depend upon its reducing power. Fehling's solution, which is in common use both as a qualitative and quantitative test for dextrose, is a solution of 34.64 gm. of pure crystallized copper sulphate, 173 gm. of Rochelle salt, and 80 gm. of sodium hydroxide in a liter of

distilled water. One c.c. of this solution is exactly reduced and decolorized by 50 milligrams of dextrose. For qualitative detection, alkaline solutions of copper, bismuth, indigo-carmine, picric acid, or silver may be used. Dextrose undergoes alcoholic fermentation with great ease, and is used in large quantities in making beer.

Dextrose readily forms compounds with metallic oxides and with many salts. When heated, many of these compounds—more particularly those of copper, bismuth, and mercury—decompose, yielding a precipitate of either the metal or its oxide.

Dextrose readily undergoes alcoholic, lactic, and butyric fermentations. When it is mixed with finely divided gastric membrane, it is rapidly changed into lactic acid. There is some evidence of the existence of unorganized ferments in the stomach, which can convert lactose and dextrose into lactic acid, and this is probably the origin of a part of the lactic acid found in the gastric contents during the digestion of dextrose. It is an assimilable sugar, though not so readily so as levulose. When injected into the circulation of a dog, the greater part of it passes unchanged into the urine.

Phenyl-glucosazone.—$C_6H_{10}O_4.(C_6H_5N_2H)_2$. This compound, produced by dextrose with phenyl-hydrazin, occurs in yellow needles. It is prepared under the conditions mentioned under lactose, for the preparation of phenyl-lactosazone. The formation of these crystals is employed as a test for glucose in urine. To 50 c.c. of the suspected urine add 1 or 2 gm. of phenyl-hydrazin hydrochlorate, 2 gm. sodium acetate, and heat on a water-bath for a half hour ; or add 10 to 20 drops of pure phenyl-hydrazin and an equal number of drops of 50 per cent. acetic acid, and warm as before. On cooling, if not before, the glucosazone separates out as yellow, crystalline needles. This test will detect 0.5 gm. of glucose per liter.

Galactose, or **cerebrose,** $C_6H_{12}O_6$, is formed, together with dextrose, when lactose and a number of other carbohydrates, especially gums and mucilages, are hydrolyzed by boiling with dilute mineral acids. It is also formed by the decomposition of the glucoside **cerebrin,** found in the brain. Dextrose and galactose may be separated by crystallization and by taking advantage of the fact that galactose is soluble in absolute alcohol, while dextrose is not. In reactions and behavior, galactose resembles dextrose, but has a considerably greater rotatory power. It yields phenyl-galactosazone with phenyl-hydrazin, which has the same composition and very similar properties to those of the corresponding compound of dextrose. Galactose is fermentable with yeast, but less readily than dextrose. It is the aldehyde of dulcitose.

Mannose, $C_6H_{12}O_6$, is obtained by the careful oxidation of mannite, and by the hydrolysis of many natural carbohydrates, especially

the cellulose from palm-nuts, vegetable-ivory nuts, etc., by heating them with dilute H_2SO_4. It is a hard, friable powder, easily soluble in water and fermentable with yeast.

THE KETONE GROUP.

Levulose, or Fructose.—$C_6H_{12}O_6$. This sugar occurs mixed with dextrose in the natural sources of that sugar, mentioned above. It is obtained with dextrose in invert-sugar, prepared by heating cane-sugar with dilute acids. It differs from dextrose in being less fermentable and in its rotatory power, which is left-handed instead of right-handed; the other differences are of minor importance, except sweetening power, which is greater in this sugar than in grape-sugar.

Levulose is easily assimilated when pure, and is completely and easily burned in the body. Its use does not increase the sugar in the urine of diabetics. It has been recently introduced as a sweetening agent for diabetics, under the name of **diabetin.** It yields a compound with phenyl-hydrazin, identical with that derived from dextrose. It forms a compound with calcium hydroxide, which, unlike that yielded by dextrose, is extremely insoluble, and may be employed for the separation of these two sugars.

Acrose, $C_6H_{12}O_6$, is a synthetical sugar obtained by Emil Fischer from acrolein, $CH_2.CH.COH$, an aldehyde obtained by superheating fats or glycerin. It is interesting from the fact that from it mannose, dextrose, and levulose have been artificially prepared.

Inosite, $C_6H_{12}O_6.2H_2O = (CHOH)_6.H_2O$, is optically inactive and does not react with phenyl-hydrazin. It occurs sparingly in the human body. It has been found in the heart, muscles, in diabetic urine, and in that of Bright's disease. It has also been found in the lungs, kidneys, spleen, liver, and brain. It occurs in abundance in the vegetable kingdom, especially in unripe beans, from which it may be conveniently prepared. Its sweet taste is its only resemblance to the sugars. It is now believed to be a derivative of benzene, and not a sugar at all.

Pure inosite forms large, efflorescent, rhombic tables, or occurs in tufted lumps of fine crystals. It is readily soluble in water, slightly so in dilute alcohol, and insoluble in strong alcohol and ether.

Sorbinose, or **sorbin,** $C_6H_{12}O_6$, is found in ripe mountain-ash berries. It is not fermentable. It is very sweet, and easily soluble in water. It crystallizes in hard, rhombic crystals.

DISACCHARIDS, OR SACCHAROSES.

These sugars form an important class of bodies.   They are all capable of hydrolysis by dilute acids and certain ferments, yielding monosaccharids.

This process is called inversion.   Cane-sugar, when inverted, gives dextrose and levulose, lactose gives dextrose and galactose, and maltose gives dextrose only.   Cane-sugar and lactose are not fermentable, while maltose is.   Cane-sugar does not reduce Fehling's solution, while the others do.

None of these sugars reduce Barfoed's reagent.

Cane-sugar, Saccharose, Saccharum (U.S.P., Br.), **Sucrose.** —Cane-sugar occurs in the juices of many plants, in most sweet fruits, in the nectar of flowers, and in honey.   It is found in large quantity in the juice of the sugar-cane (*Saccharum officinarum*), in sorghum (*Sorgo saccharatum*), in beet-root, sugar-maple, and in several species of palm.

Sugar is obtained principally from sugar-cane, beet-root, sorghum, and the maple, while some attempts have been made to obtain it from the common maize.

The juice of the sugar-cane is expressed by passing the stalks between steel rollers.   This juice is then mixed with milk of lime and heated to boiling to precipitate the coagulable materials, phosphates, etc.   These are removed and the clear liquid evaporated, either in open pans or in vacuum pans under a reduced pressure, to a thick syrup, and then left to crystallize.   The "raw sugar" thus obtained is drained from the "mother-liquor," which is further evaporated and again left to crystallize.   There is finally left a thick, brown liquid, called molasses or treacle, containing uncrystallizable sugar.

The raw sugar is refined by dissolving it in water, adding lime, and filtering through thick layers of bone-charcoal to remove the color. It is then evaporated in vacuum pans and allowed to crystallize.

Pure cane-sugar, when allowed to crystallize slowly from a concentrated solution, without agitation, forms large, transparent, monoclinic prisms, such as are seen in **rock-candy.**   It is soluble in onethird its weight of cold and in all proportions of hot water.   It is slightly soluble in weak, but almost insoluble in absolute alcohol.   It melts at 160° C. (320° F.), and solidifies, on cooling, to an opaque, crystalline mass, called "barley-sugar."

The rotatory power of sucrose, in solution, is taken advantage of for its quantitative determination.

When cane-sugar is boiled with dilute sulphuric acid, it takes up

water, and is converted into a mixture of dextrose and levulose, called **invert-sugar.**

$$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6.$$
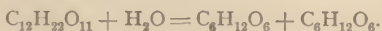
The same change takes place under the influence of yeast, or of the soluble ferment, invertin, contained in it. When heated above its melting point it gives off water, turns dark, and forms a bitter, brown, amorphous substance called **caramel,** or burnt sugar. A coloring substance called **caramel brown,** or **sucré couleur,** is made from sugar partly decomposed by heat. This is used for coloring leather, rum, whisky, beer, wine, etc. It is generally, however, made from glucose. At a higher temperature sugar continues to lose water, decomposes, and gives off inflammable gases, consisting of marsh-gas and carbon monoxide and dioxide. At a higher temperature a distillate is obtained, containing aldehyde, acetic acid, acetone, etc. Strong sulphuric acid chars sugar, leaving a black, voluminous mass. Dilute nitric acid oxidizes cane-sugar to saccharic acid, then into tartaric, and, finally, oxalic acid. A mixture of concentrated nitric and sulphuric acids forms with sugar a nitrate, $C_{12}H_{18}O_{11}(NO_3)_4$, which is amorphous and very explosive. On heating sugar with sulphuric acid and manganic oxide, a large quantity of formic acid is formed. Cane-sugar forms a series of metallic compounds called **sucrates** or **saccharates.** An aqueous solution of sugar will dissolve calcium, barium, magnesium, and lead oxides, and, with an alkali, copper and ferric oxides also. The barium salt crystallizes well.

When cane-sugar is injected into the blood-vessels of an animal, it is eliminated in an unaltered condition, and is thus shown to be unassimilated. It may be introduced in large amounts by the alimentary canal, and none of it appears in the urine. From this it appears that it undergoes a change during or before absorption. This change is the result of the action of soluble ferments appearing in the small intestine. Cane-sugar readily undergoes lactic fermentation in the presence of sour milk, to which zinc oxide is added for the fixation of the acid. It does not form a compound with phenyl-hydrazin, and by this test it may be distinguished from the other sugars.

Lactose, Milk-sugar, Saccharum Lactis (U.S.P., Br.).—C_{12}-$H_{22}O_{11}$. H_2O. This is an important ingredient of the milk of mammals, and is prepared principally from cows' milk, by evaporating the whey after removing the curd for the manufacture of cheese. Cows' milk contains from 4 to 5 per cent. of sugar, while woman's milk contains from 6 to 7 per cent. It crystallizes in large, hard prisms, has a feebly sweet taste, and is soluble in 6 parts of cold water. Yeast does not ferment it. Lactic and butyric fermentations take place readily.

Oxidizing agents yield mucic and saccharic acids. Like cane-sugar, it forms compounds with metallic oxides, and reduces alkaline copper solutions.

Ten c.c. of Fehling's fluid, which is reduced by 50 milligrams of glucose, is reduced by 6.7 milligrams of lactose. It does not reduce Barfoed's reagent.* When boiled with dilute mineral acids it yields equal molecules of dextrose and galactose, which are fermentable.

Pure lactose is not affected by yeast. Milk is capable of alcoholic fermentation under the influence of certain ferments. This has been employed from the earliest times by the inhabitants of Russia and Asia Minor in the preparation of **koumiss** and **kefyr** from mares' milk. In recent years these fluids have attracted much attention for their supposed therapeutic virtues. Very little is known of the real nature of the changes which occur in this fermentation. Kefyr ferment is a commercial article in Russia, Austria, and even in this country. Lactose, when injected into the blood-vessels, appears unaltered in the urine. It also sometimes appears in the urine in the early months of lactation or during reabsorption of milk, after weaning. It is, therefore, non-assimilable. But when taken in the alimentary canal it is perfectly assimilated. It has not been observed to undergo any change in the alimentary canal under the action of any of the secretions. Hence, the change probably takes place during absorption through the intestinal walls, as in the case of maltose. When administered in large doses lactose acts as an active diuretic. Milk loses this diuretic effect on being boiled.

Phenyl-lactosazone.—$C_{24}H_{32}N_4O_9$. This compound of lactose with phenyl-hydrazin is formed by adding to a solution of lactose equal parts of phenyl-hydrazin hydrochlorate and sodium acetate, and heating on a water-bath for one-half hour ; or by adding 10 to 15 drops of pure phenyl-hydrazin and an equal number of drops of strong acetic acid, and warming. It is soluble in 80 to 90 parts of boiling water and melts at about 200° C. It crystallizes readily in the form of yellow needles, which are usually aggregated into clusters.

Maltose, Malt-sugar.—$C_{12}H_{22}O_{11}.H_2O$. This sugar is formed by the action of malt-diastase upon starch. It may also be formed by the action of dilute acids upon starch-paste, but in this case the maltose is itself converted into dextrose. This is the chief sugar formed by the action of saliva and pancreatic juice upon starch-paste or glycogen, being accompanied, in the case of pancreatic digestion, by a variable

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* Barfoed's reagent is composed of 1 part of copper acetate in 15 parts of water. To 200 c c. of this solution 5 c.c. of acetic acid containing 38 per cent. of absolute acid is added.

THE QUALITATIVE DETECTION OF THE COMMON SUGARS. (*Allen*)

	Dextrose, $C_6H_{12}O_6$.	Levulose, $C_6H_{12}O_6$.	Milk-sugar, $C_{12}H_{22}O_{11} + H_2O$.	Maltose, $C_{12}H_{22}O_{11} + H_2O$.	Cane-sugar, $C_{12}H_{22}O_{11}$.	Dextrin, $(C_6H_{10}O_5)n$.
1. Moisten the solid sugar with water, and stir in the cold with concentrated sulphuric acid (1.845 sp. gr.).	Not affected when pure.	Not affected when pure.	Not affected.	Slightly reddish or brownish, gradually turning darker.	Charred.	Not affected.
2. Triturate the solid sugar with caustic soda, or boil it with a 3 per cent. caustic soda solution for one minute.	Deep-brown coloration.	Deep-brown coloration.	Not affected.	Slightly discoloured.	Not affected.	Not affected.
3. To the neutral aqueous solution add a few drops of Fehling's copper solution, and heat to boiling for a few minutes.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Not affected.	Not affected.
4. Heat the solution to boiling for half an hour with one-twentieth of its bulk of strong sulphuric acid, neutralize with soda, and heat to boiling with Fehling's solution for a few minutes.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.
5. To a few drops of Fehling's solution add caustic soda and ammonia, heat to boiling, and add the saccharine solution drop by drop, keeping the liquid boiling (Pavy's test).	Liquid decolorized.	Liquid decolorized.	Liquid decolorized.	Liquid decolorized.	No change.	No change.
6. Boil the solution for two minutes with 1 c.c. of a liquid containing 4 per cent. of cupric acetate, and 1 per cent. of acetic acid ($C_2H_4O_2H$).	Red precipitate of Cu_2O.	Red precipitate of Cu_2O.	No change.	No change.	No change.	No change.
7. Observe the solution in the polarimeter.	Dextro-rotatory.	Levo-rotatory.	Dextro-rotatory.	Dextro-rotatory.	Dextro-rotatory.	Dextro-rotatory.
8. Heat the solution with diluted acid, as in test 4, and observe again in the polarimeter.	Dextro-rotatory power unchanged.	Levo-rotatory power unchanged.	Dextro-rotatory power increased.	Dextro-rotatory power diminished.	Dextro-rotatory power changed to levo-rotatory.	Dextro-rotatory power diminished.

but distinct amount of dextrose. Maltose is very soluble in water. It is also soluble in alcohol, but less so than dextrose. It crystallizes, with difficulty, in fine needles. It is not easy to distinguish from glucose by qualitative tests. Its rotatory power is $+140$, while that of dextrose is 52.5 under the same conditions. With Fehling's solution, the amount of Cu_2O which separates is only about two-thirds of that which would be reduced by an equal weight of dextrose, or 6.6 parts of dextrose reduce as much copper as 10 parts of maltose. Barfoed's reagent is not reduced by maltose, while it is by dextrose. In this respect maltose resembles lactose, and this test serves to distinguish it from dextrose.

Maltose forms with phenyl-hydrazin, in the presence of acetic acid, **phenyl-maltosazone**, $C_{12}H_{20}O_9(C_6H_5N_2H)_2$. It crystallizes in minute, yellow needles, and is characterized by being soluble in about seventy-five parts of boiling water, and is still more soluble in hot alcohol. If maltose be injected into the blood-vessels it appears unaltered in the urine. To be assimilable it must, therefore, be changed before or during absorption.

Iso-maltose, $C_{12}H_{22}O_{11}$, is formed, along with maltose, by the action of diastase upon starch, and by the prolonged action of strong hydrochloric acid upon dextrose.

It is found in commercial glucose and in malt beverages. It undergoes fermentation with difficulty. It is intensely sweet.

THE POLYSACCHARIDS.

To this group belong a large number of carbohydrates of high molecular weight, generally insoluble in cold water, not diffusible, and by hydrolysis with acids split up into dextrins, disaccharids, and finally monosaccharids. The molecular weights are not definitely known, but by applying Raoult's method (p. 309) Brown and Morris found the probable molecular weight of dextrin to be $(C_6H_{10}O_5)_{12}$, and that of soluble starch $(C_6H_{10}O_5)_{30}$. By the same method that of glycogen is $(C_6H_{10}O_5)_{10}$.

The principal subgroups of the polysaccharids are the **starch group,** the **cellulose group,** and the **gum group.**

The starch group includes **starch, inulin, lichenin,** and **glycogen.**

The cellulose group includes **cellulose,** the **hemicelluloses,** and **tunicin.**

The gum group includes the **dextrins,** the **vegetable gums** and **mucilages,** and **animal gums.**

Fig 1
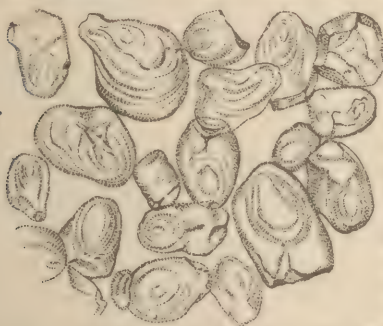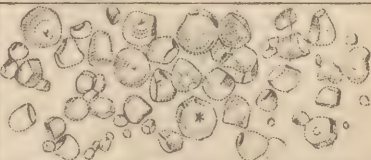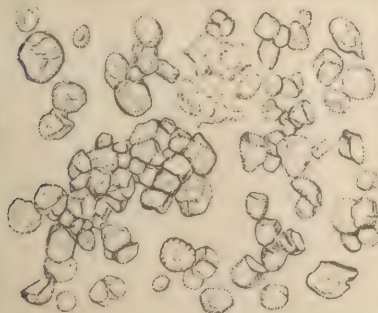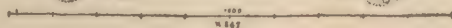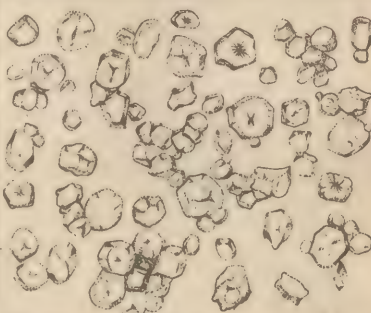
1. Potato Starch	4. St. Vincent Arrowroot	7. Rio Arrowroot
2. Bermuda Arrowroot	5. Sago of Commerce	8. Tapioca
3. Tous les Mois	6. Port Natal Arrowroot	9. Maize

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THE STARCH GROUP.

Starch, Amylum (U. S. P.).—$(C_6H_{10}O_5)_n$. This body is found in nearly all plants. It is most abundant in the cereals, rice, potatoes, and the seeds of plants. Starch occurs in the form of microscopical granules inclosed in the cells of the plant where they occur, very much as fat occurs in adipose tissue. The granules, examined under the microscope, are seen to be possessed of a distinct organized structure, which is different in each different kind of starch. They show, under the microscope, several concentric markings, arranged around a nucleus, or hilum, which is situated nearer one edge. The sizes and markings of the starches from the various sources vary sufficiently to admit of identification. This is an important fact in the detection of adulterations in food and drugs. The appearance of a number of the starches of the market, as seen under the microscope, are shown by the plate facing page 370.

Starch is prepared by grinding the grain or vegetable, and then suspending it in water, or spreading it on a sieve and running water upon it. By this means the starch-granules are washed out of the cells and remain suspended in the water. This milky-looking liquid is allowed to settle, when the starch falls to the bottom. This sediment is taken out, dried, and sent into the market.

Wheat-starch is often prepared by suspending the flour in water and allowing it to stand until the gluten is dissolved by putrefactive fermentation, when the starch may be washed and dried.

Starch is insoluble in cold water, alcohol, and ether. Heated with water to a little above 60° C. (140° F.), the contents of the granules swell up, burst the envelopes, and escape into the water. It appears at first as a very fine powder, but afterward disappears and forms an apparent solution, which, if concentrated, forms a jelly-like mass on cooling, called **starch-paste**. On long-continued boiling, starch becomes soluble dextrin. The same change is produced by a dry heat of 100° C. (212° F.), by diastase, or by dilute sulphuric acid. With diastase it soon passes into the form of dextrin and maltose. It forms metallic compounds with lead, lime, and barium oxides. Soluble starch is precipitated by alcohol and by solutions of subacetate of lead.

Starch dissolves in cold, concentrated nitric acid ; on the addition of water, **xyloidin**, a white powder, separates. The most characteristic reaction of starch is the dark blue color it forms with free iodine. This blue iodide of starch is easily decomposed, and dissociates when the solution is heated, but reforms on cooling.

Glycogen.—$(C_6H_{10}O_5)_n$. This substance resembles starch, and

occurs in the liver of man and other animals, in the embryo, yolk of egg, and some mollusks. It dissolves in cold water to an opalescent solution, but is insoluble in alcohol and ether. In many of its properties it resembles dextrin. Its solutions are dextrogyrate. A diet rich in starch, sugar, inulin, glycerin, albumin of egg, fibrin, and casein causes an increase of glycogen in the liver; while inosite, quercite, mannite, gums, and fats do not. Violent exercise, prolonged starvation, or fevers exhaust the liver of sugar. Glycogen of the liver is readily changed to acroodextrin, maltose, and dextrose by a peculiar diastasic ferment found in the liver, or by the liver-cells. Iodine gives a reddish-brown color with both dextrins and glycogen; but the color returns, with the latter, after discharging it with heat.

Glycogen may be prepared from the liver of an animal, previously fed with copious meals of carbohydrates, by cutting it in small pieces and throwing them into an excess of boiling water, using about 400 c.c to 500 c.c. for 100 gm. of the liver. After boiling for a short time, the pieces are removed and ground in a mortar to a fine powder, mixed with sand or powdered glass, and boiled again for some time. The fluid is rapidly cooled, and the proteids precipitated with double iodide of mercury and potassium with acetic acid. The solution is filtered, and the glycogen precipitated by the addition of two volumes of strong alcohol, when it may be separated by filtration and washing with absolute alcohol and ether. Glycogen, when pure, is an amorphous, white powder, readily soluble in water.

THE CELLULOSE GROUP.

Cellulose.—$(C_6H_{10}O_5)_n$. This forms the principal part of the solid framework of plants. The pure substance may be prepared by treating raw cotton or linen fiber with potassium hydroxide, acids, and ether, to remove foreign matters. It is a white solid, exhibiting the structure of the fiber from which it is obtained. It is slightly soluble in a solution of cupric hydroxide in ammonium hydroxide. On the addition of an acid to this solution it is precipitated as a white, amorphous mass. Cellulose is insoluble in water, alcohol, ether, and all ordinary solvents. Strong sulphuric acid dissolves it, and on diluting with water white flakes separate. When boiled with dilute sulphuric acid, it is slowly converted into dextrin and dextrose, and sometimes into mannose.

When cotton-wool is steeped in a cold mixture of 1 part of strong nitric and 3 parts of sulphuric acid for a few minutes, squeezed as dry as possible, placed in fresh acid for forty-eight hours, then pressed

dry, and finally washed thoroughly in water, then in a weak solution of sodium carbonate, it possesses great explosive properties, and is called **guncotton,** $C_6H_7O_2(NO_3)_3$. The appearance and physical properties of the cotton remain unchanged, but it becomes a nitrate of cellulose, the composition varying with the mode of preparation. It is used for charging torpedoes and submarine mines.

Hemicelluloses are those varieties of cellulose which yield mono-saccharids with dilute mineral acids, thus differing from the others. The cellulose of yellow lupines gives galactose and arabinose; that of rye and wheat, arabinose and xylose; that of certain nuts, mannose.

Pyroxylin is a nitrocellulose, containing less NO_3 groups than guncotton. It is prepared by dipping cotton into a mixture of 14 parts HNO_3 and 22 parts of H_2SO_4, allowing it to steep for ten hours, or until it is soluble in a mixture of alcohol and ether (1 : 3), and then removing and washing it in cold water. It is used for preparing **collodion.** A solution of pyroxylin in methyl-alcohol, acetone, methyl-acetate, or amyl-acetate is used as a lacquer for metals. This varnish is transparent, flexible, and adheres well to the metal. Pyroxylin is also used in the manufacture of **celluloid.** The moistened pyroxylin is intimately mixed with camphor, and then passed through heated rollers to melt the camphor, which in the melted state dissolves the pyroxylin. The mixture may be made transparent, or colored or mottled by the aid of admixtures of coloring matters. It is soluble in glacial acetic acid, warm nitric acid, and in hot concentrated solutions of NaOH. Ether-alcohol (3 : 1) dissolves both the camphor and pyroxylin, while ether alone dissolves out the camphor. When heated to 125° C. (257° F.), celluloid becomes plastic, and can be molded into any desired shape. It is employed to make combs, cheap jewelry, etc., imitating coral, tortoise-shell, ivory, and other materials.

Collodion is prepared by dissolving 4 parts of pyroxylin in a mixture of 70 parts of ether and 26 parts of alcohol. **Flexible collodion** is a mixture of 92 parts of the above, 5 parts turpentine, and 3 of castor oil. **Styptic collodion** owes this property to 20 per cent. of tannic acid.

If dry, unsized paper be dipped into a cold mixture of 2 parts of sulphuric acid and 1 of water for a few seconds, and then washed quickly in cold water containing a little ammonia, it is rendered very tough and strong, and is called **parchment-paper.**

Lignin is a substance usually found incrusting the cellulose of most woods. It closely resembles cellulose in composition. It is insoluble in dilute acids and alkalies, but is oxidized and dissolved by potassium chlorate and nitric acid.

It is colored an intense yellow by anilin sulphate, and a bright red by a solution of phloroglucin in hydrochloric acid. These tests will detect wood-fiber in paper when it is present.

Tunicin, or **animal cellulose,** is a similar substance found in the tissues of some animals.

THE GUM GROUP.

The gums are amorphous bodies, more or less soluble in water, but insoluble in alcohol, and are converted into one of the glucoses by dilute H_2SO_4. They are of unknown constitution, and are found in plants. They are non-volatile and have little or no taste, are non-crystallizable and eminently collodial. From this fact they are difficult to purify. Many of them appear to be closely related in composition to starch, while others have a different composition. They are distinguished from the sugars by being incapable of fermentation by yeast, and being insoluble in alcohol. The gums are distinguished from starch and dextrin by giving no color with a solution of iodine. They do not yield ammonia when heated with soda-lime, which distinguishes them from the albuminoids. They have not been sufficiently studied to admit of accurate classification.

Dextrin, or **British gum,** is an amorphous, yellowish-white, gum-like body, readily soluble in water. It is formed by heating starch above 150° C. (302° F.), or by the first action of malt-diastase or hot dilute sulphuric acid upon starch. This change is a progressive one. When diastase or pancreatic ferment is added to gelatinous starch (starch-paste), it is liquefied in a few moments, and becomes soluble starch, which is represented by the formula $10(C_{12}H_{20}O_{10})$. This is gradually hydrated under the action of the ferment, giving rise to eight different steps in the process, and eight different dextrins :

Soluble Starch, $\quad 10(C_{12}H_{20}O_{10}) + H_2O = 9(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ Maltose;
Erythrodextrin, A, $\quad 9(C_{12}H_{20}O_{10}) + H_2O = 8(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "
Erythrodextrin, B, $\quad 8(C_{12}H_{20}O_{10}) + H_2O = 7(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "
Acroodextrin, C, $\quad 7(C_{12}H_{20}O_{10}) + H_2O = 6(C_{12}H_{20}O_{10}) + C_{12}H_{22}O_{11}$ "
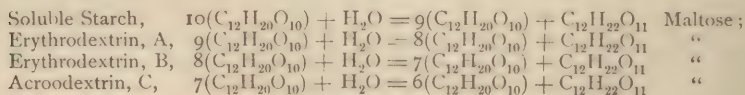
and so on until the final result obtained is :

Acroodextrin, H, $\quad 2(C_{12}H_{20}O_{10}) + H_2O = 2(C_{12}H_{20}O_{10})$ + no Maltose;
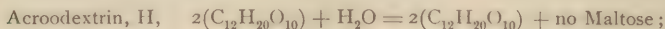
that is, the final result always leaves a portion of dextrin unchanged into maltose. The final result is about twenty per cent. of acroodextrin to eighty per cent. of maltose. Pancreatic diastase, however, has the power of slowly changing maltose to dextrose, and the lowest acroodextrin to maltose. Iodine gives a reddish color with the

erythrodextrins. It gives no color with acroodextrin. Dextrines do not reduce Fehling's solution.

Gum arabic, gum acacia, acacia (U. S. P.), is a dried exudation from the bark of different kinds of acacia. Strictly speaking, gum arabic is the generic name. Gum acacia is applied only to the purer gum employed in medicine. It is obtained chiefly from the Sudan. It occurs in rounded, irregular masses, which dissolve in cold water to form a thick, viscid solution. Gum arabic consists essentially of the calcium salt of arabic acid, or arabin. Gum arabic should not contain more than four per cent. of ash. The powder should not be colored blue (absence of starch) or red (absence of dextrin) by iodine. Its solution should give an acid reaction with litmus paper.

Arabic acid, $C_6H_{10}O_5OH_2$, when heated with dilute H_2SO_4, splits up into a series of arabinoses, of which four varieties have been recognized.

Gum senegal forms yellowish or reddish lumps, often the size of a pigeon's egg. It is less soluble than the true gum arabic, and its solution soon becomes dark in color.

Gum tragacanth is a gummy exudation from *Astragalus gummifer* and allied species. It occurs in tear-like masses, strings, or bands, which are usually marked with ridges. Gum tragacanth is usually white or yellowish-white in color, but inferior varieties are brown. It is hard, tough, and difficult to powder. It is tasteless and insoluble in alcohol and ether. It is insoluble in cold water, but it swells up and forms a thick, jelly-like mucilage. When diffused through a larger amount of water, it yields a ropy liquid. This liquid usually gives a blue color with iodine, showing the presence of starch, of which it contains from five to six per cent. Tragacanth contains about sixty per cent. of a gummy or pectinose body, which yields pectic acid on boiling with water containing one per cent. of HCl, and about ten per cent. of soluble gum, probably identical with arabin. The characteristic pectinous constituent of tragacanth is variously known as **tragacanthin, adracanthin,** or **bassorin,** and is believed to have the composition $C_{12}H_{20}O_{10}$. **Metarabin** is another gum, found in the roots of carrots, beets, etc. It is insoluble in water and is converted into arabin by treatment with diluted alkalies.

Cerasin is the insoluble part of the gum of the cherry-tree and peach-tree. By long-continued boiling with water it yields arabin.

Pectin is obtained by the action of natural ferments on pectose, an insoluble body existing in unripe fruits. It exists ready-formed in Irish moss and some other mosses. It is soluble in water, the solution gelatinizing on adding either acids or alkalies. It is precipitated by

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alcohol. By treating with bases, pectin yields pectates, which, on the addition of hydrochloric acid, give insoluble pectic acid.

Algin is obtained from various seaweeds. It is soluble in cold water, forming viscid solutions which do not gelatinize on cooling.

Carragheen is the mucilaginous constituent of Irish moss (Chondrus, U. S. P.). It is soluble in water, and is not precipitated by alcohol.

Vegetable mucilage occurs in linseed, marsh-mallow, quince-seed, elm-bark, etc. Very little is known of the composition of these bodies.

ETHERS.

A simple ether is an oxide of a hydrocarbon radical. If we substitute a bivalent oxygen atom for one hydrogen atom in each of two similar hydrocarbon molecules, we have a simple ether, thus:

$$\left.\begin{array}{c}C_2H_6\\C_2H_6\end{array}\right\} \qquad\qquad \left.\begin{array}{c}C_2H_5\\C_2H_5\end{array}\right\}O.$$
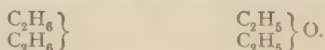
If we suppose that in a molecule of water, HOH, we remove both H atoms, and put hydrocarbon or alcohol radicals in their places, we have an ether. When the two radicals are alike it is a **simple ether**, and when unlike it is a **mixed ether.**

Examples of simple ethers:

$$CH_3\!-\!O\!-\!CH_3.$$
Methyl-ether, or Methyl-oxide.

$$C_2H_5\!-\!O\!-\!C_2H_5.$$
Ethyl-ether, or Ethyl-oxide.

Example of a mixed ether:
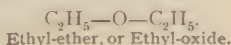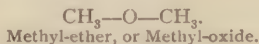
$$CH_3\!-\!O\!-\!C_2H_5.$$
Methyl-ethyl-ether.
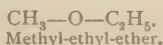
Haloid ethers, so-called, are the addition or substitution products containing one of the halogen elements. They may be regarded as binary compounds, like the haloid compounds of the metals, having a hydrocarbon radical in place of the metallic atoms.

$$\begin{array}{cc} NaBr. & NaCl. \\ C_2H_5Br. & CH_3Cl. \end{array}$$

Esters, or **compound ethers,** are compounds which may be regarded as formed by replacing one of the hydrogen atoms in a molecule of water by a hydrocarbon radical, and the other by an

acid radical. They correspond to the ternary salts of inorganic chemistry.

$$K—O—NO_2.$$
$$C_2H_5—O—C_2H_3O.$$
Ethyl-acetate.
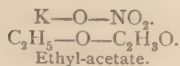
Formation of Ethers.—Ethers may be formed by the dehydrating action of H_2SO_4 upon the corresponding alcohols.

$$2C_2H_5OH — H_2O = (C_2H_5)_2O.$$

They may also be formed by the reaction of the chloride or iodide of an alcohol radical upon an alcohol in which the alcoholic hydrogen has been replaced by a metal :

$$C_2H_5ONa + C_2H_5I = C_2H_5OC_2H_5 + NaI.$$
Sodium   Ethyl-   Ethyl-ether.   Sodium
Ethylate.   iodide.   Iodide.

$$C_2H_5ONa + CH_3I = CH_3OC_2H_5 + NaI.$$
Sod. Ethylate.   Methyl-   Methyl-ethyl-ether.
             iodide.
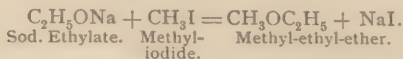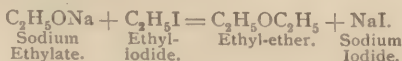
The compound ethers may be formed by warming a mixture of the alcohol and the acid, or alkaline salt of the acid, with sulphuric acid :

$$C_2H_5OH + NaC_2H_3O_2 + H_2SO_4 = C_2H_5—O—C_2H_3O + HNaSO_4 + H_2O.$$
Ethyl-   Sod. Acetate.   Acetic Ether, or
alcohol.   Ethyl-acetate.

Or by the following reaction :

$$C_2H_5I + KCHO_2 = C_2H_5—O—CHO + KI.$$
Ethyl-   Potass.   Ethyl-formate.   Potass.
iodide.   Formate.   Iodide.
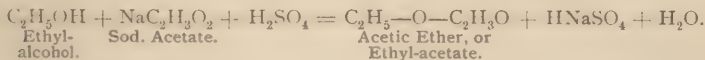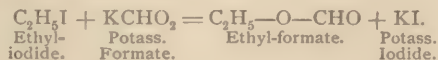
The ethers are abundantly produced by both plant and animal life. Many of the essential oils contain compound ethers. The odors of flowers, of ripening fruits, of perfumes, and the peculiar bouquet of the various alcoholic beverages are principally made up of compound ethers.

The most important class of ethers are the fixed animal and vegetable oils.

Ethers of the Paraffin Series.—**Methyl-oxide, methyl-ether,** $CH_3–O–CH_3$, is a colorless gas of an ethereal odor, soluble in water, alcohol, and H_2SO_4. It is prepared by the action of H_2SO_4 upon methyl-alcohol. It liquefies at $-36°$ C. ($-32.8°$ F.).

Ethyl-ether, ethyl-oxide, sulphuric ether, æther (U. S. P., Br.), $C_2H_5–O–C_2H_5$, is prepared by heating a mixture of ethyl-alcohol and sulphuric acid, and distilling over the resulting ether.

About 10 parts by volume of commercial alcohol and 12 parts of strong sulphuric acid are introduced into the retort, which is provided with two openings. In one of these a thermometer is placed, while into the other is inserted a funnel tube. The retort is heated until the thermometer marks 130° C. (266° F.). Alcohol is now allowed to run in slowly through the funnel tube, while the temperature is kept between 130° and 140° C. (266° and 284° F.). The ether distils off with part of the water produced, and a small quantity of alcohol and sulphurous oxide. The crude ether floats upon the water as a distinct layer. To obtain it in a pure state, it is washed with a diluted soda solution, dried over quicklime or calcium chloride, and redistilled by the heat of a water-bath. This product is called "washed ether." It still contains some water and alcohol, and for anesthetic purposes must be again purified by the same process. By the above process a small quantity of sulphuric acid may be made to etherize a very large quantity of alcohol.

The action takes place in two stages, as follows :

$$\underset{\text{Alcohol.}}{C_2H_5OH} + H_2SO_4 = \underset{\text{Ethyl-sulphuric Acid.}}{(C_2H_5)HSO_4} + H_2O.$$
$$C_2H_5HSO_4 + C_2H_5OH = \underset{\text{Ether.}}{C_2H_5\text{-}O\text{-}C_2H_5} + H_2SO_4.$$
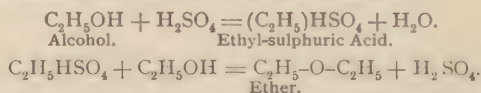
Properties.—Pure ether is a very volatile, mobile, highly refracting, colorless liquid, possessing a characteristic odor and burning taste. Specific gravity, 0.725 to 0.728 at 15° C. (59° F.). It boils at 37° C. (98.6° F.). It is soluble in ten volumes of water, and in all proportions in alcohol, chloroform, benzene, fixed and volatile oils. It is highly inflammable, burning with a luminous flame ; in handling it, therefore, care should be taken not to come near a flame. It dissolves resins, oils, and many other organic bodies. It dissolves iodine, bromine, corrosive sublimate, sulphur, and phosphorus. For anesthetic purposes, it should not affect blue litmus ; it should leave no residue when a quantity is evaporated on a watch-glass, nor should it leave a foreign odor ; it should boil in a test-tube when the latter is held in the hand, and it should not impart a blue color to ignited copper sulphate (absence of water). Twenty c.c., when shaken with an equal volume of water previously saturated with ether, should not lose more than 0.2 c.c. in volume. When 10 c.c. of ether are shaken with 1 c.c. of KOH solution and allowed to stand one hour, no color should develop (absence of aldehyde). Unless kept in well-stoppered containers, it is liable to decompose, forming aldehyde and acetic and formic acids. The above tests should be applied to ether before use as an anesthetic. A small quantity of alcohol—less than four per cent.— is not a serious objection.

It is used in preparing spirit of ether and spirit of compound ether, or Hoffman's anodyne.

Ether is largely used in medicine as an anesthetic, and is employed by inhalation, or, for local anesthesia, is sprayed upon the part. When taken in overdoses it causes death. Patients who have taken an overdose may usually be resuscitated by artificial respiration, or by the use of the induced current applied upon the neck and epigastrium. In cases of death, the odor of ether usually lingers upon the clothing and in the lungs for several hours.

COMPOUND ETHERS, OR ESTERS.

Compound ethers correspond in structure with the salts of the metals in which the metal, or positive radical, is replaced by a hydrocarbon radical.

Thus, sodium acetate corresponds with ethyl-acetate :

$$\underset{\text{Sod. Acetate.}}{Na\!-\!O\!-\!C_2H_3O} \text{ and } \underset{\text{Ethyl-acetate.}}{C_2H_5\!-\!O\!-\!C_2H_3O.}$$

Compound ethers may be formed in some cases by the direct action of the acid upon the corresponding alcohol :

$$\underset{\substack{\text{Sulphuric} \\ \text{Acid.}}}{H_2SO_4} + \underset{\substack{\text{Ethyl-} \\ \text{alcohol.}}}{2C_2H_5OH} = \underset{\substack{\text{Ethyl-} \\ \text{sulphate.}}}{(C_2H_5)_2SO_4} + \underset{\text{Water.}}{H_2O.}$$
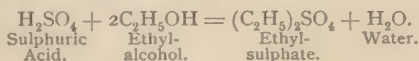
It is necessary in most cases, in order to form the ethers, to use some sulphuric acid to take up the water formed by the reaction, and for the same reason we employ the solid salt of the acid we wish to combine with the alcohol.

A second method of preparing these ethers is by first forming a haloid ether with the alcohol radical, and causing a double reaction between this and a silver salt of the acid.

$$\underset{\substack{\text{Silver} \\ \text{Nitrate.}}}{AgNO_3} + \underset{\substack{\text{Ethyl-} \\ \text{chloride.}}}{C_2H_5Cl} = \underset{\text{Ethyl-nitrate.}}{C_2H_5\!-\!O\!-\!NO_2} + \underset{\substack{\text{Silver} \\ \text{Chloride.}}}{AgCl.}$$
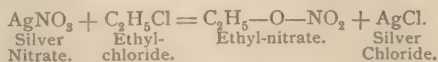
Saponification of Esters.—All compound ethers, when treated with a strong alkali, give up their acids to the alkali and set free the alcohol, or hydroxide of the hydrocarbon radical. This decomposition may often be produced by heating the ether in presence of water, with the formation of an alcohol and a free acid. It is termed **saponification**, by whatever means it is accomplished.

A large number of these compounds are known, but a few only are met with in medicine.

Methyl-nitrate, CH_3NO_3, is a colorless liquid boiling at 66° C.

Methyl-salicylate, C_6H_4–O–H.CO_2.CH_3, **methyl salicylas** (U. S. P.), **artificial oil of wintergreen**, is a colorless or yellowish liquid, having the odor and taste of oil of wintergreen (gaultheria), with the essential constituent of which it is identical. It is identical with the oil of Betula. Its sp. gr. is 1.183 to 1.185, and it boils at 219° to 221° C. (426° to 429.8° F.). It is optically inactive. It is slightly soluble in water, but soluble in alcohol, glacial acetic acid, carbon disulphide, and the volatile oils. It may be prepared by distilling a mixture of salicylic acid, wood-alcohol, and strong H_2SO_4.

It is employed as a flavoring agent, and to some extent in medicine.

Ethyl-acetate, **æther aceticus** (U. S. P., Br.), **acetic ether**, C_2H_5–O–C_2H_3O, is prepared by distilling a mixture of strong sulphuric acid, alcohol, and sodium acetate.

$$C_2H_5OH + Na(C_2H_3O_2) + H_2SO_4 = CH_3CO-O-C_2H_5 + H_2O + NaHSO_4.$$
Alcohol.   Sodium Acetate.   Ethyl-acetate.
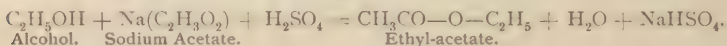
The distillate is washed with a solution of calcium chloride and milk of lime, decanted, dried over calcium chloride, and finally redistilled. Acetic ether is a colorless, limpid liquid, boiling at 76° C. (168.8° F.) and possessing a pleasant, fruity odor. It dissolves in about eight parts of water, the water becoming acid from the decomposition of a part of the ether into acetic acid alcohol. It is miscible with methyl- and ethyl-alcohols and with ether in all proportions.

It is a good solvent for the essential oils, resins, morphine, gun-cotton, and most other substances soluble in ether.

The refreshing smell of hock-vinegar and some old wines is due to the presence of acetic ether. The ether is inflammable, burning with a bluish-yellow flame and acetous odor.

Ethyl-nitrite, or **nitrous ether**, C_2H_5–O–NO, is a mobile liquid, boiling at 16.5° C. (62° F.). It has a sp. gr. of 0.947, and is insoluble in water, but freely soluble in alcohol. It is prepared by distilling a mixture of alcohol, potassium nitrite, and sulphuric acid ; or by gradually heating a mixture of equal parts of alcohol and strong nitric acid until it begins to boil, then removing the heat and allowing it to distil slowly.

$$2C_2H_5OH + 2KNO_2 + H_2SO_4 = 2C_2H_5NO_2 + K_2SO_4 + 2H_2O.$$
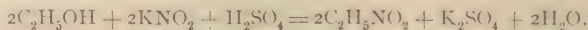
It is purified as described above for the other ethers.   **Nitro-ethane,**

$C_2H_5-N\genfrac{}{}{0pt}{}{=O}{=O}$, is isomeric with the above and differs in physical properties. It boils at 113° C. (235° F.), and is more stable than ethyl-nitrite.

Spirit of nitrous ether, spiritus ætheris nitrosi (U. S. P., Br.), **sweet spirit of nitre,** is a mixture of ethyl-nitrite, ethyl-alcohol, aldehyde, and acetic ether. It is prepared by adding to 770 gm. of sodium nitrite, dissolved in a liter of water, 550 c.c. of alcohol; the mixture is cooled by ice-water, and 520 gm. of H_2SO_4, diluted with 1000 c.c. of water, added slowly through a funnel tube. The resulting ether is then slowly distilled over.

The distillate is washed with ice-water to remove alcohol, and then with a solution of sodium carbonate, and finally dried with potassium carbonate. It is then mixed with twenty-one times its weight of deodorized alcohol.

Spirit of nitrous ether is a clear, mobile, volatile, pale-yellow, inflammable liquid, having a fragrant, ethereal odor and a sharp, burning taste. The sp. gr. is about 0.836 to 0.842 at 15° C. (59° F.). It should boil at about 65° C. (149° F.).

When 5 c.c. of the liquid are placed in a nitrometer with 10 c.c. of a 16 per cent. solution of potassium iodide, and then 10 c.c. of a normal solution of H_2SO_4 added, it should give off not less than 55 c.c. of N_2O_4. (U. S. P. test.)

Ethyl-sulphates.—There are two sulphates of ethyl, the one neutral and the other acid, corresponding to the neutral and acid sulphates. When H_2SO_4 acts upon an excess of alcohol, we have the following reaction:

$$C_2H_5OH + H_2SO_4 = \genfrac{}{}{0pt}{}{C_2H_5O}{H-O}{>}SO_2 + H_2O.$$

Ethyl- Sulphuric Ethyl-sulphuric Water.
alcohol.   Acid.   Acid.
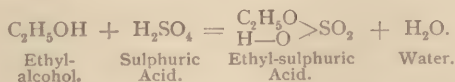
This reaction is the first step in the manufacture of ether. On heating with alcohol, this compound breaks up into ether and sulphuric acid.

Ethyl-sulphate, $(C_2H_5)_2SO_4$, is a heavy, oily, yellow liquid, prepared by mixing in a retort equal volumes of alcohol and sulphuric acid, and, after twenty-four hours, distilling off the contents of the retort at about 150° C. to 160° C. (302° to 320° F.).

$$2C_2H_5OH + H_2SO_4 = (C_2H_5)_2SO_4 + 2H_2O.$$
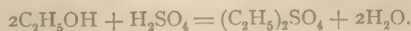
This oily liquid is known as **heavy oil of wine.** When mixed with an equal volume of ether it forms the **oleum æthereum** of the

U. S. P. It is used in making the compound spirit of ether—
spiritus ætheris comp. (U. S. P., Br.).

Ethyl-carbamate, or Urethane.—C_2H_5–O–$C \genfrac{}{}{0pt}{}{\diagup NH_2}{= O}$. This compound ether is formed by acting upon ethyl-carbonate with ammonia at 100° C. (212° F.). Ethyl-carbonate is prepared by treating silver carbonate with ethyl-iodide:

$$2C_2H_5I + Ag_2CO_3 = (C_2H_5)_2O_2CO + 2AgI.$$
$$(C_2H_5)_2CO_3 + NH_3 = C_2H_5-O-CO-NH_2 + HOC_2H_5.$$
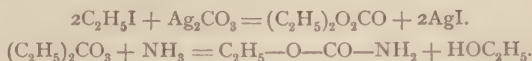
Or, by the action of urea nitrate upon alcohol at a temperature of 120° to 130° C. (248° to 266° F.).

$$CO(NH_2)_2HNO_3 + C_2H_5OH = NH_4NO_3 + NH_2CO-O-C_2H_5.$$

Urea Nitrate. Ethyl-alcohol. Am. Nitrate. Ethyl-carbamate.

The resulting urethane is extracted with ether and recrystallized.

Urethane occurs as odorless, colorless, columnar, or tabular crystals, with a taste resembling nitre. It melts at 47° C. (116.6° F.), and distils at 180° C. (356° F.). It is readily soluble in water and most other media.

Tests.—Heated with H_2SO_4, it gives off CO_2 and traces of alcohol. Heated with KOH it gives off ammonia. If 1 gm. be dissolved in 10 c.c. of water, and 2 gm. of sodium carbonate and a few granules of iodine added, and the mixture gently warmed, iodoform separates on cooling. Urethane is used in medicine as a hypnotic in doses of 1 to 2 gm. **Somnal** is a solution of chloral and urethane in alcohol.

Ethyl-benzoate, valerianate, butyrate, nitrate, etc., are prepared very much in the same way as the above ethers, using the salts of the acids here indicated with alcohol and sulphuric acid.

Amyl-acetate, C_5H_{11}–O–C_2H_3O, is prepared by distilling a mixture of amyl-alcohol, sulphuric acid, and sodium acetate. It has a pleasant, ethereal odor.

It is manufactured on a considerable scale for use as a flavoring agent for confectioners.

Amyl-nitrite,* **amyl nitris** (U. S. P., Br.), C_5H_{11}–O–NO, is prepared by passing nitrogen trioxide, N_2O_3, into amyl-alcohol. It is a colorless or slightly yellow liquid, and possesses the choking smell of amyl compounds generally. It boils at 96° C. to 99° C. (205° to 210° F.). Specific gravity, 0.872 to 0.874. Its vapor, when inhaled,

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* Amyl-nitrate is frequently ordered or written by mistake when the nitrite is meant.

produces at first a sense of fullness in the head and dizziness; then flushing of the face, increased heart-action, and lowering of the blood-pressure and temperature. It may contain as impurities nitric acid, amyl-nitrate, amyl-valerianate, and hydrocyanic acid.

It is almost insoluble in water, but mixes in all proportions with ether and alcohol. It is very volatile even at low temperatures, and is inflammable.

The method of assaying amyl-nitrite is the same as that described for spirit of nitrous ether, page 383; 0.26 gm. should yield about 40 c.c. of gas.

Salol, phenyl-salicylate, $C_6H_5-O-C_7H_5O_2$, is prepared by heating a mixture of sodium phenyl, sodium salicylate, and phosphorus oxychloride. The reaction is as follows:

$$2C_6H_5ONa + 2C_6H_4OHCOONa + POCl_3 =$$
Sod. Phenol.   Sod. Salicylate.

$$3NaCl + NaPO_3 + 2C_6H_4OHCOOC_6H_5.$$
Phenyl-salicylate.
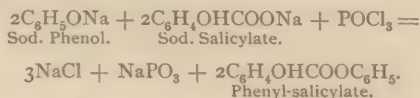
Another method is to heat salicylic acid in a flask to 220° to 230° C. (428° to 446° F.) in an atmosphere of inert gas, as CO_2, when it loses water and CO_2, and is converted into salol.

$$2C_6H_4 \begin{cases} OH \\ COOH \end{cases} CO_2 + H_2O + C_6H_4 \begin{cases} OH \\ COOC_6H_5 \end{cases}$$
Salicylic Acid.   Phenyl-salicylate.
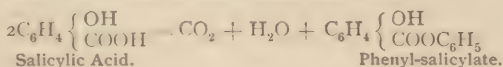
Or by the reaction of $COCl_2$ on salicylic acid. Salol is found in the market as a white crystalline powder, almost insoluble in water, having a faint aromatic odor and a slightly salty taste. It is soluble in ether, alcohol, benzene, and fatty oils. It melts to a colorless, oily liquid at 43° C. (110° F.). It is not a very stable compound, and easily breaks up into carbolic and salicylic acids. With fixed alkalies it breaks up into salicylate and an alkali phenol. This change takes place with bile in the duodenum. It is used in medicine as an intestinal antiseptic and in the treatment of rheumatism.

Salacetol, acetol salicylate, $(CH_3COCH_2)CO_2C_6H_4OH$, is a compound recently introduced into medicine as a substitute for salol, from which it differs in having the radical acetol, C_3H_5O, in place of the phenyl radical, C_6H_5.

Salacetol is prepared by heating together monochloracetone and sodium salicylate:

$$C_6H_4 \begin{cases} OH \\ COONa \end{cases} + CH_3COCH_2Cl = C_6H_4 \begin{cases} OH \\ COO(CH_2COCH_3) \end{cases} + NaCl.$$
Sodium Salicylate.   Monochloracetone.   Salacetol.
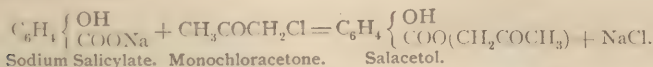
Salacetol occurs in white, shining leaflets, melting at 71° C. (160°

33

F.), very slightly soluble in water, soluble in 15 parts of cold alcohol, in 25 parts of castor oil, or in 30 parts of almond or olive oil. It contains 71.1 per cent. of salicylic acid in combination with the absolutely non-toxic substance, acetol, a homologue of levulose. Salacetol may, therefore, be regarded as a synthetical glucoside. It is, like salol, decomposed by alkalies into acetone and an alkaline salicylate. It reduces Fehling's solution.

It has been used as an intestinal antiseptic and in rheumatism, both internally and by inunction. It may be given in doses as large as two or three grams.

Salicyl-acetic acid, $C_6H_4 \begin{cases} OCH_2COOH \\ COOH \end{cases}$, is closely related to salacetol, although not an ester. It is prepared by the action of monochloracetate of sodium upon disodium salicylate.

$$C_6H_4 \begin{cases} ONa \\ CO_2Na \end{cases} + NaCH_2ClCO_2 = C_6H_4 \begin{cases} OCH_2CO_2Na \\ CO_2Na. \end{cases} + NaCl$$

Disod. Salicylate.   Sodium Monochlor-   Disodium
                         acetate.   Salicyl-acetate.
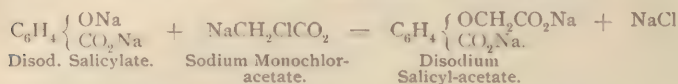
The sodium salt is dissolved in water, and the acid is set free with hydrochloric acid. The acid is said to possess great antiseptic powers.

Salophen, acetyl-para-amido-phenyl salicylate,

$$C_6H_4 < \begin{matrix} OH \\ COO.C_6H_4NH(C_2H_3O), \end{matrix}$$
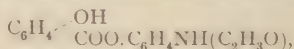
may be regarded as salol in which an atom of hydrogen in the phenyl group has been replaced by the univalent group $NHCOCH_3$.

Salophen occurs in minute, white, crystalline scales, almost entirely insoluble in water, and free from odor and taste. It is freely soluble in alcohol and ether. The alcoholic solution gives a violet-colored precipitate with Fe_2Cl_6, and a dense-white one with bromine water. It melts at 187° C. (368.6° F.). Like salol, it splits up in the body, and is excreted as salicyluric acid and paraphenol compounds. It is comparatively harmless.

Salol-camphor is prepared by fusing a mixture of three parts salol and two parts camphor. It is a colorless, oily liquid, soluble in ether, chloroform, and oils.

Betol, *β-naphthol salicylate,* $C_6H_4(OH)COOC_{10}H_7$, has been used for the same purposes as salol. It occurs as a white, crystalline powder, almost insoluble in water.

Fruit Essences.—Many of the compound ethers are found in the essential oils of plants and fruits. Salicylic aldehyde or salicylous acid, $C_6H_4 \begin{cases} OH, \\ COH, \end{cases}$ is the essential oil of meadow-sweet, and may

be prepared artificially by the oxidation of salicin. Methyl-salicylate, $C_6H_4 \left\{ \begin{array}{l} OH, \\ COOCH_3, \end{array} \right.$ composes almost entirely oil of wintergreen (Ol. gaultheriæ, U. S. P.) and oil of birch (Ol. betulæ volatile, U. S. P.). This last may be prepared artificially by heating chloroform and sodium phenol.

Artificial Fruit Flavors.—These flavoring extracts have come into use extensively in recent years, and are manufactured largely from various mixtures of compound ethers, organic acids, and glycerin. The following formulæ will give some idea of the character of these mixtures: **Pineapple** consists of chloroform, 1 part; aldehyde, 1 part; ethyl-butyrate, 5 parts; amyl-butyrate, 10 parts; and glycerin, 3 parts. **Strawberry,** of ethyl-nitrate, 1 part; ethyl-acetate, 5 parts; ethyl-formate, 1 part; ethyl-butyrate, 5 parts; methyl-salicylate, 1 part; amyl-acetate, 3 parts; amyl-butyrate, 2 parts; glycerin, 2 parts. **Pear,** of ethyl-acetate, 5 parts; amyl-acetate, 10 parts; benzoic acid, 1 part; and glycerin, 10 parts.

The ethers are to be dissolved in pure alcohol (sp. gr., 0.83), and the numbers given indicate the quantity to be added to 100 parts of alcohol by measure. The mixtures, when taken in large quantities, produce deleterious effects; but as the quantities actually used are very small, they probably produce no appreciable effects. Besides the above-mentioned and many other " fruit essences," these ethers are also extensively employed to improve the flavor of poor wines, and to fraudulently imitate wines, brandy, rum, whiskies, etc.

ETHERS OF GLYCERIN, OR GLYCERIDS.

As glyceryl, or propenyl, C_3H_5, the radical of glycerin, is a trivalent radical, it can and usually does unite with three molecules of a mono-basic acid. It is possible, however, to have three glycerids with a monobasic acid, just as we have three salts of the tribasic phosphoric acid (see p. 237). Thus, when we act upon glycerin with HCl, we can form monochlorhydrin, $C_3H_5 \left\{ \begin{array}{l} OH \\ OH, \\ Cl \end{array} \right.$ dichlorhydrin, $C_3H_5 \left\{ \begin{array}{l} OH \\ Cl, \\ Cl \end{array} \right.$ and

trichlorhydrin, $C_3H_5 \left\{ \begin{array}{l} Cl, \\ Cl, \\ Cl, \end{array} \right.$ In like manner we have monoformin,

diformin, and triformin, by replacing one, two, or three of the hydroxyls of glycerin with the radical of formic acid. The compound ethers of glyceryl and the acids of the first or paraffin series compose most of the natural fixed oils and fats. For this reason the acids

formed from this series are called collectively the **fatty acids.** The trinitrate of glyceryl has already been described. The natural fixed oils and fats are composed of mixtures, in most cases, of two or more of these glycerids. The principal glycerids are given below.

The glycerids are named from the organic acid which they contain, ending in -**in.** The prefixes mon-, di-, tri- are used to indicate the number of acid radicals the molecule contains.

NATURAL FATS AND FIXED OILS.

NAME.	FORMULA.	OCCURRENCE.
Monoformin,	$C_3H_5(OH)_2OCHO,$	Artificial ester.
Diformin,	$C_3H_5(OH)(OCHO)_2,$	" "
Monoacetin,	$C_3H_5(OH)_2OC_2H_3O,$	" "
Triacetin,	$C_3H_5(OC_2H_3O)_3,$	*Euonymus europæus.*
Tributyrin,	$C_3H_5(OC_4H_7O)_3,$	Butter.
Trivalerin,	$C_3H_5(OC_5H_9O)_3,$	Solid excrement and dolphin oil.
Tricaproin,	$C_3H_5(OC_6H_{11}O)_3,$	{ Butter, cocoanut oil.
Tricaprylin,	$C_3H_5(OC_8H_{15}O)_3,$	{ Fæces, cocoanut oil, butter.
Tricaprin,	$C_3H_5(OC_{10}H_{19}O)_3,$	Cocoanut oil, goats' milk.
Trilaurin,	$C_3H_5(OC_{12}H_{23}O)_3,$	Cocoanut, palm-nut, and bayberry oils.
Trimyristin,	$C_3H_5(OC_{14}H_{27}O)_3,$	Cocoanut oil, palm-nut oil, nutmeg but- ter, cows' butter, and goose-fat.
Trilinolein,	$C_3H_5(OC_{18}H_{31}O)_3,$	Linseed, poppy, sunflower, hemp-seed oils.
Triolein,	$C_3H_5(OC_{18}H_{33}O)_3,$	Oils (Olive oil).
Tripalmitin,	$C_3H_5(OC_{16}H_{31}O)_3,$	Oils and fats (Palm oil).
Tristearin,	$C_3H_5(OC_{18}H_{35}O)_3,$	Animal fats (Tallow).

Almost all the fats and fixed oils are compound ethers of glyceryl, C_3H_5'''. They are found in both the animal and vegetable kingdoms. Some are liquid, while others are solid. Some oils remain permanent in the air, like olive oil, while others oxidize and thicken, like linseed and poppy oil. These latter are called siccative, or drying oils. The fats are insoluble in water, difficultly soluble in alcohol, but soluble in ether, petroleum naphtha, and carbon disulphide. The composition of natural oils will be further considered while describing the fatty acids. So far as known, no natural fat consists purely of one sub- stance, but of a mixture of oleate, palmitate, and stearate of the triad radical, glyceryl, C_3H_5.

These fats are decomposed by heat, acrolein being one of the products.

Tristearin, or **stearin,** $C_3H_5(C_{18}H_{35}O_2)_3$, is found in the more solid fats. It may be separated from the other principles by melting tallow with turpentine, when the stearin remains in solution, while the olein and palmitin are precipitated.

By adding water to this liquid, the stearin may be separated. It fuses at 71° C. (160° F.) and solidifies again at 50° C. (122° F.).

Tripalmitin, $C_3H_5(C_{16}H_{31}O_2)_3$, is the chief constituent of mutton-fat, lard, and human fat. It is more soluble in alcohol and ether than stearin. It crystallizes in fine needles, and its melting point is at 46° C. (115° F.).

Triolein, $C_3H_5(C_{18}H_{33}O_2)_3$, is the fluid constituent of most fats and oils. When pure, it is a colorless fluid, becoming yellow on exposure to the air. It may be obtained from olive oil by treating it with cold alcohol, cooling the solution to 0° C. (32° F.) to separate the palmitin, and adding water to the alcoholic solution to precipitate the olein. Olein is more abundant in vegetable than in animal oils.

When treated with hot alkalies or superheated steam, the fats are saponified. Most fats decompose slowly in contact with air, and become rancid. In the process of digestion they are partially saponified and then emulsified—*i. e.*, broken up into minute drops. The active agents in this change are the bile and pancreatic secretion. The emulsification and absorption of partially saponified fats take place with greater ease than with pure fat ; hence, a slightly rancid oil is more easily assimilated than a fresh one.

The sources of fat in the human body are : (1) the fat taken as food ; (2) the decomposition of proteids ; (3) the carbohydrates, a portion of which are converted into fat.

These oils are termed "**fixed**" to distinguish them from the volatile or essential oils described in another place. The "**volatile**" oils evaporate or volatilize without decomposition, while the fixed decompose when volatilized, giving off irritating vapors of **acrolein**, C_3H_4O. When rubbed upon paper they render it translucent, the spot remaining more or less permanent. They are, when pure, nearly tasteless and odorless, unctuous to the touch, insoluble, and float upon water. Some of them absorb oxygen when exposed to the air, and become thick and gummy. These are called **drying** or **siccative** oils. The fixed oils are usually obtained by pressure, with or without the aid of heat.

Olive oil, oleum olivæ (U. S. P., Br.), is a well-known oil expressed from the fruit of the olive-tree. It is a yellow or greenish-yellow oil, almost odorless, and of a bland, sweetish taste. The finest grades have a greenish tinge, and are prepared by submitting the fruit to cold pressure. Olive oil is frequently adulterated, chiefly with poppy oil, sesame oil, cotton-seed oil, and peanut oil. The method of detection of adulterations will be seen by reference to the table on page 396. The sp. gr. of olive oil is 0.915 to 0.918. It is very sparingly soluble in alcohol, but readily soluble in ether, chloroform, or carbon

disulphide. When cooled to about 10° C. (50° F.), it begins to deposit crystalline particles, and at 0° C. (32° F.) it forms a white, granular mass.

Almond oil, oleum amygdalæ expressum (U. S. P., Br.), is a fixed oil expressed from bitter or sweet almonds, a clear, pale straw-colored or colorless oil, almost inodorous and having a mild, sweet taste. The pure oil has no odor of bitter almonds. Its sp. gr. is from 0.915 to 0.920. It is slightly soluble in alcohol, and is readily soluble in ether and chloroform. If 2 c.c. of the oil be mixed with 1 c.c of fuming nitric acid and 1 c.c. of water, a white or reddish-brown mixture should be formed, which should separate, on standing some hours, into a white, solid mass and a scarcely colored liquid.

Earth-nut or **peanut oil, arachis oil,** is obtained from the nuts of *Arachis hypogea*, the oil being chiefly expressed in France. The nut contains about forty-five per cent. of the oil. It is of a pale greenish-yellow color, of a distinctly nutty flavor and smell, and is used very largely in the adulteration of olive oil, lard oil, and other oils.

Cotton-seed oil, oleum gossipii seminis (U. S. P.), is a fixed oil expressed from the seeds of *Gossipium herbaceum*, or the cotton-plant, and subsequently purified. It is a pale-yellow oil without odor, and having a bland, nut-like taste. Its sp. gr. is 0.920 to 0.930. It is largely employed as a substitute for, or an adulterant of, olive oil, as a substitute for lard in cooking, in the manufacture of butterine and soap, and for adulterating other oils.

Sesame or **teel oil, benne oil, oleum sesami** (U. S. P.), is a fixed oil expressed from the seeds of *Sesamum indicum*. It is a yellow, inodorous, and bland oil resembling cotton-seed oil, and used for the same purposes. It is an imperfect drying oil, and does not readily turn rancid. Its behavior with reagents will be seen by reference to the table.

Cod-liver oil, oleum morrhuæ (U. S. P., Br.), is a fixed oil obtained from the fresh livers of the cod, *Gadus morrhua*. It is obtained by pressure, either with or without the aid of heat. Several qualities of cod-liver oil are recognized in commerce : a pale oil of a straw-yellow color ; a pale brown oil of inferior quality, also used in medicine ; and a dark brown variety obtained by roughly boiling down the livers, and known as **tanners' oil.** When fresh, the best grades of oil are almost colorless and limpid, with a slight odor and taste and a faint acid reaction. On standing, the fishy taste and odor, as well as the acid reaction, increase. Cod-liver oil consists essentially of several glycerids, the chief one being olein, with variable quantities of myristin, palmitin, stearin, with small quantities of cholesterin and

free fatty acids. Cod-liver oil contains traces of iodine and some-
times bromine, but the form in which these elements exist is
unknown. A peculiar acid called **gaduic acid**, and another substance
called **gadium**, and two alkaloids, **asselin** and **morrhuin**, have
been found. Gautier has obtained butylamin, amylamin, hexylamin,
and hydrodimethyl-pyridin. To which of these substances cod-liver
oil owes its value as a therapeutic agent is still a matter of doubt.
Heyerdahl claims that when made from fresh livers and without
exposure to air, it does not contain any of these alkaloids. He finds
that it does contain two fats, **therapin** and **jecolein**. Therapin,
$C_3H_5(OC_{17}H_{29}O)_3$, constitutes about twenty per cent. of the oil, while
jecolein, $C_3H_5(OC_{34}H_{66}O)_3$, forms about the same amount ; the rest he
has not thoroughly studied. The property which is probably the chief
recommendation for its use is the facility with which it is digested or
assimilated. This characteristic is not due to the traces of biliary
compounds, which are nearly always present. It may in part be due
to the readiness with which cod-liver oil becomes rancid or saponifies,
as slightly rancid oils are more easily emulsified than neutral oils, and,
as it very easily saponifies, this would favor its emulsification and
absorption. Cod-liver oil is seldom adulterated.

Linseed Oil, Flaxseed Oil, Oleum Lini (U. S. P., Br.).—It
is a dark-yellow, fixed oil, expressed from ground linseed without the
use of heat. It has a characteristic disagreeable odor and taste.
Linseed oil consists of about eighty per cent. of linolein, with smaller
quantities of olein, myristin, and palmitin. Linolein is a glycerid of
linoleic acid. The drying property of linseed oil is due to the pres-
ence of linolein, which absorbs oxygen from the air and is converted
into a gummy mass resembling resin. The varieties of linseed oil
recognized in commerce are raw, refined, artists', and boiled. The
tendency of linseed oil to oxidize is much increased by heating it to
a high temperature while passing a current of air through and over
the oil, and subsequently increasing the temperature until the oil
begins to effervesce. The temperature employed is from 130° C.
(266° F.) upward. This process is termed boiling the oil. The oil
thus treated is called boiled oil. By continued boiling the oil be-
comes very thick, and may be drawn out into elastic threads. This
product is used in the manufacture of printing-ink. By adding
litharge, ferric oxide, or manganese oxide to the oil during the boil-
ing process, the oxidation and consequent drying properties of the oil
are increased. The salts of lead and manganese are most employed
in the manufacture of "driers" for linseed oil.

Castor oil, oleum ricini (U. S. P., Br.), is usually obtained by
the extraction of the oil by the expression of the seeds of *Ricinus com-*

munis, which contain nearly one-half their weight of oil.   If not clear, the oil is treated with animal charcoal or magnesia, and filtered. It is a thick, viscid, transparent, colorless or greenish-yellow liquid, having a faint odor and a disagreeable taste.   At a low temperature it thickens and deposits white granules, and at about —18° C. (—0.4° F.) it solidifies.   Castor oil differs from most other fixed oils by its density, viscosity, and its ready solubility in alcohol and insolubility in naphtha.   Its sp. gr. is 0.950 to 0.970.   Nitric acid attacks it energetically, and converts it into suberic acid.   Ammonia precipitates from it a crystalline solid.   It is used in medicine as a laxative.

Palm oil has a reddish-yellow to a brown color, and varies in consistency from that of soft lard to that of tallow.   As met with in commerce, it is frequently contaminated with water and solid impurities, and is more or less rancid. .

Cacao-butter, oleum theobromatis (U. S. P., Br.), is a fixed oil expressed from the seeds of *Theobroma cacao*.   It is a yellowish-white solid, having a faint, agreeable odor and a bland, chocolate-like taste. Its sp. gr. is from 0.970 to 0.980.   It is readily soluble in chloroform and ether, and is soluble in 120 parts of boiling absolute alcohol or 100 parts of cold alcohol.   It does not easily become rancid.   Its fusing point is between 30° and 33° C. (86° to 91.4° F.).   It is a brittle solid at ordinary temperatures.

Croton oil, oleum tiglii (U. S. P.), **oleum crotonis** (Br.), is expressed from the seeds of *Croton tiglium*.   It is a pale yellow or brownish-yellow, somewhat viscid and slightly fluorescent liquid, having a slight fatty odor and a mild, oily, afterward acrid and burning taste.   Croton oil contains, besides the glycerids of oleic, crotonic, and fatty acids, a peculiar principle called crotonol, to which the oil owes its vesicating properties.   When applied to the skin, it produces a pustular eruption, and when taken internally is a drastic cathartic. The oil has an acid reaction to litmus paper.   It is soluble in alcohol, its solubility increasing with age.   It is very soluble in ether, alcohol, chloroform, and in the fixed and volatile oils.

Neat's-foot oil is obtained by the heat of boiling water or steam upon the feet of cattle, horses, sheep, and other animals, a process popularly called "trying out."   It is a straw-yellow, odorless, nearly tasteless liquid.   It is not readily prone to rancidity.

Lard oil, oleum adipis (U. S. P.), is extracted from lard at a low temperature.   It is a light yellow, transparent oil, used in cooking, soap-making, and in artificial butter, or butterine.   It is very frequently adulterated, principally with cotton-seed and other seed oils, rape oil, earth-nut oil, etc.

Tallow is the fat of the ox or sheep, obtained by gentle heat.

It is a white or yellowish-white, brittle solid, used largely in the manu-facture of soap and candles. Tallow oil, or **oleo oil**, is obtained by expression with gentle heat, the more liquid portion running out and the more solid portion remaining behind in the press. This oil is especially prepared for the manufacture of **oleomargarine.**

Butter consists of a mixture of stearin, palmitin, and olein not soluble in water, and the glycerids of butyric, caproic, caprylic, and capric acids. These last acids, when free, are soluble and volatile. Oleomargarine, butterine, suine, etc., are artificial mixtures of butter with foreign fats, made to imitate butter.

The principal foreign fats employed are lard, beef oil, cotton-seed, sesame, and similar oils. The usual method of manufacture is to melt the foreign fats, deodorize them, when necessary, with nitric acid, then either to mix them with genuine butter or churn them with milk. The mixture usually has a melting point above or below that of genuine butter.

Melting points of various fats :

Butterine, ... $31.3°$ C. ($88.5°$ F.).
Cacao-butter, ... $34.9°$ C. ($94.7°$ F.).
Butter (average), ... $35.8°$ C. ($96.6°$ F.).
Beef-dripping, ... $43.8°$ C. ($111.1°$ F.).
Veal dripping, ... $47.7°$ C. ($118°$ F.).
Lard, ... $42°$ C. to $45°$ C. ($107.5°$ to $113°$ F.).
Mutton fat, ... $50°$ C. to $51°$ C. ($122°$ to $123.8°$ F.).
Tallow (beef), ... $53°$ C. ($127.4°$ F.).

A low melting point generally indicates butterine, or vegetable oils, while a high one indicates the presence of animal fats.

The detection of foreign substances in butter is a matter of consid-erable importance, owing to the fact that certain countries have laws prohibiting the sale of artificial butter, or at least restricting its sale.

The modern butter substitutes are close imitations of natural butter, and can only be detected by chemical processes dependent upon the difference in chemical composition of butter-fat and other animal or vegetable oils. The butter-fat is saponified with a solution of KOH, the soap thus produced is again decomposed with a mineral acid, and the fatty acids are separated. Stearic, oleic, and palmitic acids are insoluble in water, while butyric acid and certain others are soluble. Butter-fat, when thus treated, yields from 5 to 8 per cent. of soluble acids and from 85.5 to 88.5 per cent. of insoluble acids. The sum of the insoluble and soluble fatty acids should always amount to fully 94 per cent. of the fat taken. The other fats and oils, when saponi-fied by this method, yield mere traces of the volatile or soluble fatty acids, and from 95.5 to 97.7 per cent. of insoluble acids. These

variations are taken advantage of for the identification of genuine butter or the detection of mixtures. In actual practice 2.5 gm. of the purified butter-fat are taken and saponified with KOH, the soap decomposed with diluted H_2SO_4, and the mixture submitted to distillation. The soluble or volatile acids distil off, and are estimated by titration with a standard alkali. From the amount of alkali required to neutralize the volatile acids, the quantity or percentage may be calculated. The insoluble acids remain behind in the distilling flask. If it be desired to do so, they may be filtered out and weighed. Another method that is sometimes employed for the detection of adulteration in butter is the amount of alkali, KOH, required to saponify a known weight of butter. This is known as its saponifying equivalent. It is determined by adding to a known weight of the purified butter-fat an excess of standard solution of KOH, and heating until saponification is complete. The excess of KOH is then estimated by a standard acid. The difference between that added and the free alkali remaining gives that in combination with the fatty acids of the butter, or the saponifying equivalent. The amount of alkali required for the saponification of butter is much greater than that of most other oils. Another method which is depended upon to distinguish butter from other fats or oils is the amount of iodine or bromine that a given weight of butter-fat will absorb under prescribed conditions. For particulars concerning these various processes we must refer the student to special works on the subject.

Identification of Fixed Oils.—Various methods have been devised for the identification of fixed oils and fats. Some of these depend upon the separation of the fat into its constituents, and the quantitative estimation of these constituents. These processes are rendered necessary because of the extensive adulteration to which commercial oils and fats are subjected. Some of these processes are designed especially for the detection of the falsification of butter. Others are applicable only to the commercial oils other than butter. One of the leading characteristics of oil is its sp. gr., which is usually determined by the use of the sp. gr. flask, the method of using which has been described in part I. In the first column of the table, page 396, will be found the sp. gr. of the principal oils there mentioned. The liquefying temperature is another characteristic property of oils which is made use of for their identification. These temperatures are given in the third column of the table. Of the chemical methods that are employed for the identification of fixed oils, only the simpler ones can be here described.

The rise of temperature which ensues on treating a fixed oil with H_2SO_4 is the measure of the extent or intensity of the chemical reac-

tion between the two. This rise of temperature has been taken advantage of by Maumené for the identification of many of the fixed oils. It is found that with a given oil the rise is fairly uniform.

The results are more uniform when bromine is used in place of sulphuric acid. The method may be conducted as follows : * Take a seven-inch long test-tube, and wind a layer of cotton about the closed end. Place this in a six- or eight-ounce beaker, or ordinary tumbler, and fill the latter with calcined magnesia to a depth of two and a half inches, packing it down around the test-tube and cotton. The test-tube may now be taken out, leaving a non-conducting nest lined with cotton. Two gm. of the oil are dissolved in enough chloroform to make exactly 10 c.c. Five gm. of bromine are dissolved in enough chloroform to make 50 c.c. The solutions are brought to the room-temperature, and 5 c.c. of the oil-chloroform solution are carefully measured out with a pipette and run into the test-tube, taking care not to soil the sides of the tube. The tube is now returned to the nest in the beaker, the thermometer placed in the solution, the temperature taken, and 5 c.c. of the bromine solution slowly added from a pipette, consuming about one to two minutes in adding the 5 c.c. As soon as the last drop of bromine solution has been added, the temperature of the mixture is observed and the highest point reached on the scale noted. The difference between the initial temperature and this reading gives the *heat of bromination* of 1 gm. of bromine acting upon 1 gm. of the oil under examination. The heat of bromination of the commoner oils, when the above directions are followed, is given in the fourth column of the table on the next page.

With some oils, sulphuric acid gives characteristic colorations. The next two columns of the table show the effect produced in placing a drop or two of sulphuric acid in the center of about twenty drops of the oil, and observing the color before and after stirring. The colors produced by different samples of the same kinds of oils are liable to some variations from those indicated in the table. Many of the fixed oils give characteristic color reactions with nitric acid as well as with sulphuric acid. The method of applying the test is to agitate together from 3 to 5 c.c. of the oil with 1 c.c. of nitric acid of sp. gr. 1.32. Heat the mixture for five minutes in boiling water, and then take it out and observe the color of the oil from time to time for an hour and a half. If the acid be of a higher sp. gr. than 1.32, it will be unnecessary to apply the heat. The colors given by this test are to be found in the last column of the table on page 396.

The elaidin reaction is also a characteristic test for many of the fixed oils. It depends upon the action of nitrous acid upon the oleic

TABLE FOR THE IDENTIFICATION OF THE PRINCIPAL FIXED OILS.

REAGENTS AND CONDITIONS.

Name of Oil.	Specific Gravity at 15° C.	Solidifying Temperature, C.	Rise in Temperature of 1 Gm. Oil, 1 Gm. Br.	H_2SO_4 Color Tests: 1 to 2 Drops, 20 Drops Oil.	Same After Stirring.	Color Test with HNO_3. 3 to 5 Drops Oil. 1 Drop Acid. Sp. Gr., 1.32.
Olive,	.914 to .917.	+4 to 6.	20° C. to 23° C.	Yellow - green to brown.	Light brown or olive green.	Colorless or yellow to green.
Almond,	.914 to .920.	−10 to 20.	20° C. to 21° C.	Yellow or colorless.	Dark yellow to brown.	Colorless changing to solid.
Cotton-seed,	.922 to .930.	1 to 4.	24° C.	Bright red.	Dark red to black.	Red or orange.
Sesame (Teel Oil),	.921 to .924.	+5 to −5.	23° C.	Brown.		Yellow to orange.
Linseed,	.930 to .937.	−20 to −27.	30° C. to 31° C.	Brown, hard clot.	Mottled brown.	Red or orange.
Castor,	.950 to .970.	−18.	20° C. to 22° C.	Yellow to pale brown.	Nearly colorless to pale brown.	Transient yellow or orange.
Croton,	.942 to .955.		26° C.			
Linseed (boiled),	.939 to .959.		30° C.	Hard, brown clot.	Mottled dark brown.	Red or orange.
Cacao-butter,	.995 at 98° C. = .857	30 to 34.				
Cocoanut,	at 98° C. = .868 to .874.	20 to 28.	3-3° C.			
Neat's-foot,	.914 to .916.	Below 0° C.	13° C. to 16° C.			
Lard,	.915.	4 to 10.	18° C.	Greenish-yellow to brown.	Mottled or dirty brown.	Colorless or transient yellow.
Cod-liver,	.925 to .931.		34° C. to 35° C.	Dark red spot with purple streaks.	Purple to brown or reddish.	Brownish-red.
Beeswax,	.959 to .969 (at 98° C. = .819 to .829).	62 to 64.				

acid of the oils, by which it is changed into elaidic acid, which is solid at ordinary temperatures. The best method of obtaining this reaction is with the following solution : One c.c. of mercury is dissolved in 12 c.c. of cold concentrated nitric acid. One c.c. of this freshly made solution is then shaken in a wide-mouthed, stoppered bottle with 25 c.c. of the oil to be tested, the agitation being kept up at intervals for from one to two hours. When treated in this manner, oils consisting of nearly pure olein give a solid product of greater or less consistency. Olive oil is remarkable for the firmness of the lemon-yellow elaidin production. The behavior of the more important fixed oils when tested in this manner is as follows :

Elaidin Test.—Behavior of most important fixed oils.

(*a*) A solid, hard mass :

Olive, almond, arachis, lard, sperm, and sometimes neat's-foot.

(*b*) A buttery consistency :

Neat's-foot, mustard, sometimes sperm, arachis, and rape.

(*c*) A buttery mass separating from·a liquid :

Rape, sesame, cotton-seed, cod-liver, seal, whale, and porpoise.

(*d*) Liquid products :

Linseed, hempseed, walnut, and other drying oils.

Fat in the Human Body.—Fats which occur in the animal body are chiefly mixtures of triolein, tripalmitin, and tristearin in varying proportions, with small quantities of tricaproin and trivalerianin. The normal fat of each animal, or class of animals, is characteristic in its composition. Thus, in the fat of man and the carnivora, palmitin is in excess over the other two. In the fat of herbivora, stearin predominates, and in that of fishes, olein. The fat of butter, as seen above, contains several other glycerids in addition to these three. The fat that is accumulated in the animal body during fattening can not be accounted for by the fat given as food. A large part of it may come from the conversion of proteids and carbohydrates into fat. The manner in which this conversion takes place has been the subject of considerable dispute. The belief now is, however, that both proteids and carbohydrates can give rise to the production of fat in the animal body. The total amount of fat in the human body varies within wide limits, but from three to five per cent. may be taken as a fair average. It is generally greater in women and children than in men. It is generally greater in middle age than during old age, although sometimes this rule is reversed. The object of the storage of fat in the human body is to provide a surplus of heat-producing elements for periods of starvation and disease. It also serves to lubricate the different organs, to give rotundity to the form, and to protect the internal structure from sudden changes of temperature, owing to

its non-conductivity of heat. The principal service of fat in the economy is as a producer of heat and energy, by its oxidation. In wasting diseases and starvation, the fats previously stored up are rapidly consumed to sustain the body. In cold climates, therefore, more fats are demanded than in temperate or hot climates. When fat is taken in excess of that needed by the body, it is either discharged in the feces or it is absorbed and stored up as fat.

Soaps.—Soaps are metallic salts of the fatty acids—*i. e.*, oleic, palmitic, and stearic. Those of potassium, sodium, and ammonium are soluble in water ; those of the other metals are insoluble. Hard soaps are salts of the fatty acids with sodium ; soft soaps are salts of potassium. Soaps are made from almost any fat, but the best varieties are made from lard, olive, peanut, or palm oils. Cocoanut- and palm-oil soaps are much used at sea, on account of their property of dissolving in salt water. Castor oil is extensively employed for making transparent toilet-soaps, and now very extensively used for soap-making. Lard-soaps are very white, solid, inodorous, and valuable for toilet use. Ordinary yellow soap is made by saponifying tallow or palm oil with soda. More or less resin is often added, but the use of too large a proportion renders the soap dark. The principal soaps of commerce contain either an excess of unsaponified oil or fatty acid, on the one hand, or an excess of alkali, on the other. The alkali of the soap may be either as a carbonate or as caustic alkali. Such soaps are said to be alkaline soaps. Small quantities of foreign substances are frequently added to soaps, as coloring, perfume, or medicinal agents. Medicated soaps are now sold which contain a considerable proportion of medicinal agents, such as carbolic, salicylic, or cresylic acids ; thymol, tar, sulphur, ichthyol, naphthaline, camphor, etc. An excess of glycerin is sometimes added, which is a valuable ingredient in certain soaps. In the manufacture of soap, the alkali is either heated with the fat or with the free fatty acids previously set free with superheated steam. In the first case the glycerin is left in the soap ; in the second the glycerin has been removed. After the formation of the soap, it is separated from the solution either by evaporating down and allowing it to solidify, or by precipitating it from its solution by the addition of salt. The flaky precipitate rises to the surface, is separated, melted, and cast into molds.

White castile soap, sapo (U. S. P.), **sapo durus** (Br.), is a soda soap made from olive oil. It is strongly alkaline, hard, yet easily cut when fresh, having a faint, peculiar odor free from rancidity, and a disagreeable alkaline taste. It is soluble in water and in alcohol ; more readily with the aid of heat.

Ammonia soap occurs in **linimentum ammoniæ** (U. S. P.,

Br.). This liniment is made from ammonia-water and cotton-seed oil, with the addition of five per cent. of alcohol.

Soft soap, green soap, sapo viridis (U. S. P., 1880), **sapo mollis** (U. S. P., Br.), is a potassium soap made from linseed oil. It is a soft, unctuous mass of a yellowish-brown color, soluble in about five parts of water to a clear liquid. It is also readily soluble in alcohol.

Lead soap, lead plaster, emplastrum plumbi (U. S. P., Br.), is a soap prepared by saponifying olive oil with oxide of lead. It is a yellowish-white, pliable or tenacious, but not greasy mass, gradually acquiring a brownish color on exposure to the air. It is insoluble in water, but is soluble in benzene and chloroform. When a solution of a soluble soap is added to a water containing the heavier metals in solution, an insoluble soap is usually produced. Hard waters usually owe their hardness to the salts of calcium and magnesium. The soaps produced in this case are the insoluble calcium and magnesium soaps. Acids decompose soaps, liberating the fatty acids and forming other salts with the metal.

Lime soap is a constituent of **linimentum calcis** (U. S. P., Br.), or **carron oil.** This is prepared by shaking together equal volumes of lime-water and either linseed or olive oil.

ALDEHYDES.

The aldehydes are compounds formed by the oxidation of the primary alcohols. Only those alcohols containing the group $C<^{OH}_{H_2}$ can form aldehydes, which group become $C^{=O}_{-H.}$ They differ from the corresponding alcohols by having two atoms of hydrogen removed; thus, ethyl-alcohol forms ethyl- or acetic aldehyde.

$$CH_3 - C<^{H_2}_{OH} + O = CH_3 - C^{=O}_{-H} + H_2O.$$
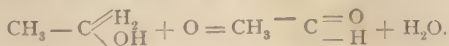
By further oxidation aldehydes yield the corresponding acids. It will be observed that, as two atoms of hydrogen have been removed without putting any atoms in their places, aldehydes are unsaturated bodies. On this account they are very liable to undergo changes with reagents. They are especially prone to undergo oxidation to produce acids, and therefore act as strong reducing agents. They can also take up hydrogen when treated with sodium amalgam, and regenerate the alcohol. They combine with ammonia to form **aldehyde ammonias,**

and with the acid sulphites of the alkalies to form crystalline compounds. Aldehydes unite with hydoxylamin, NH_2OH, to form **oximes**, and with hydrazines to form **hydrazones.** They restore the red color to magenta (rosanilin hydrochlorate) which has been reduced and decolorized with sulphurous acid. This is used as a test for aldehydes in general. With chlorine and bromine they unite to form the chloride or the bromide of the oxygenated radical. With H_2S they form sulphaldehydes.

1. $2C_2H_3OH + O_2 = 2C_2H_3OOH.$
2. $C_2H_3OH + H_2 \text{ (nascent)} = C_2H_5OH.$
3. $C_2H_3OH + NH_3 = C_2H_4{<}{OH \atop NH_2}.$
4. $C_2H_3OH + Cl_2 = C_2H_3OCl + HCl.$
5. $C_2H_3OH + H_2S = C_2H_3SH + H_2O.$

Preparation.—1. Formaldehyde and polymers of this compound (glucose, etc.) are formed in growing plants. (See part v.)

2. The aldehydes may be artificially formed by partial oxidation of primary alcohols.

$$2C_2H_5OH + O_2 = 2C_2H_3OH + 2H_2O.$$
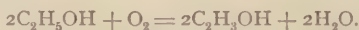
3. They may also be prepared by the action of nascent hydrogen (sodium amalgam) upon the chlorides or anhydrides of the corresponding acids.

$$\underset{\text{Acetyl Chloride.}}{C_2H_3OCl} + H_2 = \underset{\text{Acetic Aldehyde.}}{C_2H_3OH + HCl.}$$

$$\underset{\text{Acetic Anhydride.}}{{C_2H_3O \atop C_2H_3O}{>}O} + 2H_2 = \underset{\text{Acetic Aldehyde.}}{2C_2H_3OH + H_2O.}$$
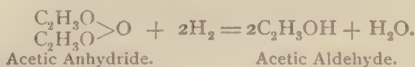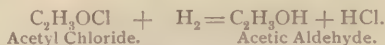
4. By distilling a mixture of the calcium salt of the corresponding acid with calcium formate.
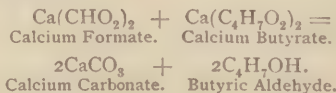
$$\underset{\text{Calcium Formate.}}{Ca(CHO_2)_2} + \underset{\text{Calcium Butyrate.}}{Ca(C_4H_7O_2)_2} =$$

$$\underset{\text{Calcium Carbonate.}}{2CaCO_3} + \underset{\text{Butyric Aldehyde.}}{2C_4H_7OH.}$$

Formaldehyde, $CH_2O = C{=O \atop \diagdown H}{-H}$, is produced by the dry distil-

lation of calcium formate, or by the oxidation of methyl-alcohol. It is a gas at ordinary temperatures, and on standing it is gradually polymerized into paraformaldehyde, $C_3H_6O_3 = 3(CH_2O)$, a crystalline solid. When formaldehyde is left in contact with lime-water, it forms a mixture of formose, $C_6H_{12}O_6$, and acrose, $C_6H_{12}O_6$. This reaction is one of the steps in the formation of other sugars by

synthesis. Formaldehyde, as a forty per cent. solution in water, is sold under the name of **formalin.** It is used as an antiseptic and food preservative. The gas is generally used for room disinfection, and is either prepared by specially constructed lamps for burning wood-alcohol, or the gas is set free from formalin by some dehydrating agent, like calcium chloride, in a closed cylinder, or by boiling the liquid.

Acetic aldehyde, aldehyde, C_2H_4O, is prepared on a large scale in the manufacture of alcohol, when it distils over with the first of the distillate. Commercial alcohol generally contains traces of aldehyde.

It may be prepared by distilling from a retort a mixture of 3 parts of crystals of potassium dichromate, 4 parts of sulphuric acid, 12 parts of water, and 4 parts of alcohol. The receiver must be placed in a freezing mixture. Manganese dioxide may be used instead of the dichromate.

The impure aldehyde thus obtained is treated with dry calcium chloride to remove water, and then mixed with twice its volume of ether, surrounded by a freezing mixture, and saturated with dry ammonia-gas. The crystalline aldehyde-ammonia thus formed is separated and distilled, with dilute sulphuric acid, from a flask or retort connected with a well-cooled receiver. It may then be freed from water by standing over fused calcium chloride and redistilling.

Aldehyde is a colorless, transparent, mobile liquid, boiling at 21° C. (69.8° F.). It has an acrid, suffocating odor, irritating the eyes. It mixes in all proportions with water, alcohol, and ether.

It acts as a strong reducing agent. If mixed with a solution of ammoniated silver nitrate and warmed, the silver is reduced and deposited upon the glass in the form of a mirror. It gives the general reactions of the aldehydes. A general test for the aldehydes is their property of restoring the red color of a solution of fuchsin which has been decolorized with sulphurous acid.

The vapor of aldehyde, when inhaled, produces asphyxia. When the liquid is taken internally it produces intoxication. When pure aldehyde is left for some time in contact with HCl, SO_2, $COCl_2$, or $ZnCl_2$, it undergoes a change, forming two polymeric compounds known as paraldehyde and metaldehyde.

Paraldehyde, $(C_2H_3OH)_3$, or CH_3—CH $\left\{ \begin{array}{l} CH_3—COH \\ CH_3—COH \end{array} \right\} O$, **paraldehydum** (U. S. P., Br.), is used in medicine as a hypnotic. It is prepared by treating aldehyde with a very small quantity of HCl or with $ZnCl_2$. The temperature of the liquid rises, and almost complete conversion into paraldehyde takes place. Purification is effected

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by freezing out and rectifying. Paraldehyde is a clear, colorless liquid, with an ethereal odor and a burning, afterward cooling taste. Specific gravity, 0.998. Boils at 124° C. (255.2° F.), and congeals to a crystalline mass at 10° C. (50° F.). One part dissolves in ten of water, forming a neutral solution, miscible in all proportions with alcohol and ether. $BaCl_2$ and $AgNO_3$ solutions should give no precipitate with it (absence of sulphates and chlorides), and it should give no coloration after two hours' contact with a solution of KOH or NaOH (absence of aldehyde). It may be given in doses of 20 to 40 minims.

Metaldehyde, $(C_2H_4O)_n$, is formed from aldehyde by H_2SO_4 or HCl gas at a temperature below 0° C. (32° F.). It is a white, crystalline solid, occurring in needles or prisms. When heated, it sublimes without melting at 112° to 115° C. (234° to 239° F.). It is insoluble in water, but soluble in hot alcohol and ether.

It also has been used as a hypnotic.

Sulphaldehyde, C_2H_3SH, is prepared by the action of H_2S upon aldehyde. It is an oily liquid with a disagreeable odor. When treated with acids it polymerizes like aldehyde, producing a solid thioparaldehyde, giving physiological effects like those of paraldehyde.

Of the large number of aldehydes known, a few occur in natural products of vegetable origin.

Benzoic aldehyde, C_6H_5COH, occurs in **oil of bitter almonds.** It is prepared in the fruit by the decomposition of the glucoside, **amygdalin,** by the ferment **emulsin.** It is a colorless or pale yellow, oily liquid, with a characteristic odor. It is prepared artificially from toluene.

Cinnamic aldehyde, C_8H_7COH, occurs in the oils of cinnamon and cassia. When oxidized it gives cinnamic acid.

Salicylic aldehyde, $C_6H_5O.COH$, or oil of spiræa (meadowsweet), is prepared from salicin by distilling with H_2SO_4 and $K_2Cr_2O_7$.

Cuminic aldehyde occurs in the oils of cumin, caraway, etc.

Vanillic aldehyde, or **vanillin**, $C_7H_7O_2.COH$, is extracted from the vanilla bean-pods. It is now made artificially from **coniferin,** a glucoside obtained from the pine family.

Trichloraldehyde, or **chloral**, CCl_3—COH, is aldehyde in which the three hydrogen atoms of the radical have been replaced by three chlorine atoms; thus: $C_2H_3OH.C_2Cl_3OH$. It is prepared by passing dry chlorine into absolute alcohol until it is saturated. The liquid separates into two layers. The lower layer is separated and shaken several times with H_2SO_4, and finally distilled from the acid. It is thus obtained as a colorless, oily liquid, having a pungent, irritating odor and a bitter, acrid, caustic taste. It boils at 94.5° C.

(202° F.) ; sp. gr., 1.502. It is very soluble in water, alcohol, and ether. It dissolves the halogens, sulphur, and phosphorus. It answers to all the general tests of the aldehydes mentioned above. Oxidizing agents convert it into **trichloracetic acid,** C_2Hl_3OOH, a colorless, crystalline solid, soluble in water. Trichloracetic acid has been used as a delicate test for albumin in the urine. Chloral is converted into chloroform and a formate by the alkaline hydroxides.

$$C_2Cl_3OH + NaOH = NaCHO_2 + CHCl_3.$$

This reaction is employed to prepare a very pure chloroform for anesthetic purposes. It unites with water to form **chloral hydrate,** $C_2Cl_3OH.H_2O$, **chloral** (U. S. P.), a colorless, transparent, crystalline solid, having a pungent odor and an acrid taste. It volatilizes slowly at ordinary temperatures, fuses at 57° C. (134.6° F.), and boils at 98° C. (208° F.), with partial decomposition into water and chloral. Chloral hydrate is readily soluble in water. Under the influence of sunlight, potassium chlorate decomposes chloral with violence.

Chloral combines with a considerable range of organic substances. When dissolved in alcohol the temperature rises, and **chloral alcoholate** crystallizes out, $CCl_3C\overline{H}{}^{OH}_O{}_{C_2H_5}$. Chloral liquefies when triturated with an equal weight of camphor, menthol, thymol, phenol, salol, or acetanilid.

Action on the Economy.—It has been claimed that the action of chloral on the economy is due to the formation of chloroform and a formate, by decomposition after absorption, or in the intestine. Such is probably not the case.

When taken in an overdose, chloral acts as a poison, thirty grains having proved fatal, although five or six times that amount has been taken by others with no bad effect. The symptoms of poisoning by chloral are not uniform or very characteristic. Strychnine has been recommended as a physiological antidote. The stomach should be emptied, and stimulants given freely. Death is likely to occur from heart-depression.

Tests.—Chloral may be detected in the contents of the stomach by rendering them alkaline with KOH, heating on a water-bath, and conducting the vapors through a red-hot tube, and then allowing them to bubble through a solution of $AgNO_3$. If chloral is present it decomposes, giving off chloroform, which is decomposed, in passing through the hot tube, into HCl and free chlorine. The HCl gives a white precipitate of AgCl. The same experiment without the addition of KOH, if it gave positive results, would prove the

presence of chloroform, and not chloral, in the contents of the stomach. If the use of chloral hydrate be long continued, it induces **a chloral habit.**

Chloral combines with ammonia to form **chloral-ammonia,**

CCl_3—C—OH, a white crystalline powder, consisting of fine needles, with the structure showing CCl_3—C bonded to H, OH, and NH_2

fusible at 62° to 64° C. (143.6° to 147.2° F.), soluble in water, and easily decomposing when in solution. It has been used as a hypnotic in doses of fifteen to thirty grains.

Chloral shows a readiness to combine with the compound ammonias, amids, and camphors. **Chloral-ammonium (chloralamid), chloral-formamid, chloralimid, chloral-menthol, chloral-urethane,** and a number of like compounds, or mixtures, have been introduced and advocated as remedies for various purposes. Most of these are mentioned elsewhere.

Hypnal is a crystalline body formed by the action, at ordinary temperatures, of chloral hydrate upon antipyrin in solution. It is a tasteless, odorless body, soluble in five or six parts of water.

It is used as a hypnotic and anodyne.

Croton chloral, or **butyl-chloral,** $C_3H_4Cl_3COH$, bears the same relation to butyl-alcohol that chloral does to ethyl-alcohol.

C_2H_5OH	C_2H_3OH	C_2Cl_3OH
Ethyl-alcohol.	Aldehyde.	Chloral.
C_4H_9OH	C_4H_7OH	$C_4H_4Cl_3OH$
Butyl-alcohol.	Butyl-aldehyde.	Trichlorbutyl-aldehyde, or Croton Chloral.

It is prepared by substituting aldehyde for alcohol in the preparation of chloral.

It is an oily liquid of pungent odor, boiling at 164° C. (327.2° F.). It combines with water to form **croton chloral hydrate, butyl-chloral hydras** (Br.), a crystalline solid used in medicine as a hypnotic.

Chloral-oximes are a class of bodies formed by the reaction of hydroxylamin with aldehydes and ketones, and have recently been recommended as hypnotics. The following chloral-oximes have been prepared: **Chloral-acetoxime,** $CCl_3COH_2.ON \begin{cases} CH_3 \\ CH_3 \end{cases}$; **chloral-acetaldoxime,** $CH_3CH_3 = NOCH(OH)CCl_3$; **chloral-benzaldoxime,** $C_6H_5CH = NOCH(OH)CCl_3$; **chloral-camphoroxime,** $C_{10}H_{16} = NOCH(OH)CCl_3$. All these oximes are crystalline compounds easily soluble in alcohol and ether, and are decomposed by hot water.

Chloralose, or **anhydrogluco-chloral,** $C_8H_{11}Cl_3O_6$, is the name given to a compound formed by heating chloral and glucose for one hour at 100° C. (212° F.).

$$CCl_3COH + C_6H_{12}O_6 = C_8H_{11}Cl_3O_6 + H_2O.$$
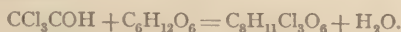
It forms fine, colorless needles, melting at 184° C. (363° F.). It is soluble in 170 parts of water at 15° C. (59° F.), readily soluble in alcohol and ether. It has a bitter taste. It has been recommended as a substitute for chloral, and is claimed to be free from the unpleasant after-effects of chloral upon the heart.

ACETALS.

The acetals are formed by the union of alcohol with aldehydes, with the elimination of water, or by the oxidation of the alcohols, when the aldehyde formed reacts upon part of the alcohol. They may be regarded as compounds formed by replacing the oxygen of an aldehyde with two oxyalcoholic radicals.

Methylal, $CH_2 \diagdown^{OCH_3}_{OCH_3}$, is obtained by oxidizing methyl-alcohol with sulphuric acid and manganese dioxide, distilling the mixture and collecting that portion coming over between 40° C. and 50° C. (104° F. and 122° F.). The product is redistilled, and freed from water by standing in contact with dry K_2CO_3. The reaction is first to oxidize the methyl-alcohol to formaldehyde, which reacts upon more CH_3OH.

$$CH_2O + 2CH_3OH = \overline{CH_2}^{OCH_3}_{OCH_3} + H_2O.$$
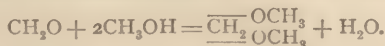
Methylal is a colorless, mobile liquid, with a penetrating ethereal odor, and boiling at 42° C. (107.6° F.). It is soluble in thirteen parts of water, and in alcohol, ether, fixed and volatile oils. It should not decolorize potassium permanganate solutions acidified with sulphuric acid. Strong H_2SO_4 decomposes it, but alkalies do not.

It has been used as a hypnotic, and as a cerebral sedative.

Acetal, $CH_3CH \diagdown^{OC_2H_5}_{OC_2H_5}$, is formed when acetic aldehyde is heated with alcohol for some time.

$$\underset{\text{Aldehyde.}}{CH_3 - COH} + \underset{\text{Alcohol.}}{2C_2H_5OH} = \underset{\text{Acetal.}}{CH_3 - \overline{CH}^{OC_2H_5}_{OC_2H_5}} + H_2O$$
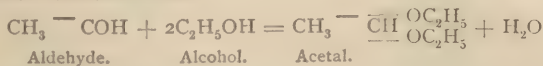
It is also found in raw-grain alcohol.

It is a colorless liquid of agreeable taste, boiling at 104° C. (219° F.).

KETONES.

These bodies are the first result of the oxidation of secondary alcohols—*i. e.*, upon an alcohol that contains the group $C{-H \atop O-H}$ instead of $C{\diagup H_2 \atop O-H}$, as in the primary alcohols.

The ketones all contain the group CO. The relation of these bodies will be made clear by the following graphic formulæ:

$$
\begin{array}{c}
C\equiv H_3 \\
| \\
H-C-O-H + O \\
| \\
C\equiv H_3
\end{array}
\rightleftarrows
\begin{array}{c}
C\equiv H_3 \\
| \\
C=O + H_2O. \\
| \\
C\equiv H_3
\end{array}
\qquad
\begin{array}{c}
C{-O-H \atop =H_2} \\
| \\
C-H_2 + O \\
| \\
C\equiv H_3
\end{array}
=
\begin{array}{c}
C{=O \atop -H} \\
| \\
C-H_2 \\
| \\
C\equiv H_2
\end{array}
\cdot H_2O.
$$

Isopropyl-alcohol.   Dimethyl-ketone, or Acetone.   Propyl-alcohol.   Propyl-aldehyde.
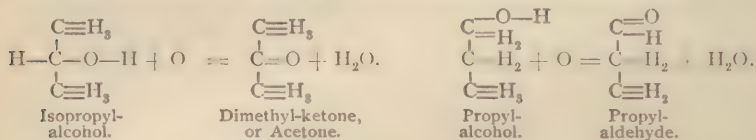
In the nomenclature of the ketones, the name is made to contain the names of all the radicals attached to the CO″ group. Thus, **ethyl-methyl-ketone** would express the name of the following: $C_2H_5 \, \overline{} \, CO \, \overline{} \, CH_3$.

Ketones are distinguished from aldehydes by their behavior with reagents.

Nascent hydrogen regenerates the secondary alcohol from ketones and a primary alcohol from aldehydes. Oxidation produces with aldehydes the corresponding acid, while the oxidation of ketones splits the molecules, with the formation of two acids.

$$
\begin{array}{c}
C\equiv H_3 \\
| \\
C=O + O_2 = \\
| \\
C\equiv H_3
\end{array}
\begin{array}{c}
C{=O \atop -OH} \\
| \\
C\equiv H_3
\end{array}
+
\begin{array}{c}
C{=O \atop -OH} \\
| \\
H
\end{array}
$$

Acetone.   Acetic Acid.   Formic Acid.
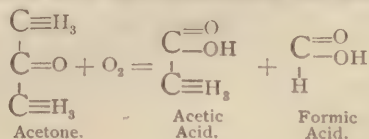
Acetone, acetyl-methylid, dimethyl-ketone, $(CH_3)_2CO$, is formed by the dry distillation of the acetates, sugar, tartaric acid, and by a number of other reactions. It is usually obtained by the distillation of calcium acetate.

$$2Ca(C_2H_3O_2)_2 = 2(CH_3)_2CO + 2CaCO_3.$$

Calcium Acetate.   Acetone.   Calcium Carbonate.
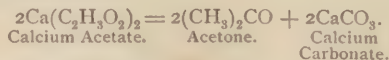
It may be prepared by passing the vapor of a sixty per cent. acetic acid through a rotating tubular still, containing pumice-stone or barium carbonate, heated to a dull-red heat (Squibb).

$$2HC_2H_3O_2 = C_3H_6O + CO_2 + H_2O.$$

Acetone is present in very small quantities in normal urine and blood, but in larger quantities in the acetonuria of diabetes mellitus. It is a transparent, colorless liquid, having a peculiar ethereal odor. It is miscible with alcohol and ether. It is miscible in water, but separates on the addition of salts. It shows the aldehyde reaction with fuchsin and sulphurous acid. It is a good solvent for resins, fats, camphor, guncotton, etc. It is used as a solvent in varnish manufacture. Its sp. gr. is 0.7966. It boils at 56° C. (132.8° F.). Chlorine or bromine, in presence of alkalies, convert it into chloroform or bromoform, and this reaction is employed for the preparation of chloroform.

Sulphur Derivatives of the Hydrocarbons and Alcohols.— As we have seen in inorganic chemistry, sulphur can replace oxygen in many compounds, especially where it acts as a linking atom. Thus, corresponding to H_2O we have H_2S; to NH_4OH, NH_4SH; to H_2CO_3, H_2CS_3. So in alcohols we may have sulphur take the place of oxygen. These compounds are frequently called **mercaptans** (mercuro captum), from their property of readily taking up mercury. They may be more properly named sulpho-alcohols or thio-alcohols. In the ethers and aldehydes we may have the same substitution of sulphur for oxygen, giving rise to sulphides of the hydrocarbon radicals, or sulphaldehydes. These compounds, as a class, are generally ill-smelling compounds, and are frequently produced in the putrefactive fermentation of organic substances containing sulphur. The following is a list of some of the more important of this class of compounds:

SULPHIDES OF THE HYDROCARBON RADICALS.

Methyl-sulphide. $(CH_3)_2S$
Methyl disulphide, $(CH_3)_2S_2$
Methyl-trisulphide, $(CH_3)_2S_3$
Methyl-hydrosulphide, CH_3SH
    (methyl mercaptan)
Ethyl-hydrosulphide, C_2H_5SH
    (mercaptan)
Ethyl-oxysulphide, $(C_2H_5)_2SO$
Ethyl-sulphonic Acid, $C_2H_5SO_2OH$

Diethyl-sulpho-dimethyl-methane, or
    Sulphonal, $(CH_3)_2C(SO_2C_2H_5)_2$
Diethyl-disulphide, $(C_2H_5)_2S_2$
Diethyl-trisulphide, $(C_2H_5)_2S_3$
Diethyl-tetrasulphide, $(C_2H_5)_2S_4$
Diethyl pentasulphide, $(C_2H_5)_2S_5$
Diethyl oxysulphide, $(C_2H_5)_2SO_2$
    (ethyl-sulphone)
Xanthic Acid, C_2H_5OCSSH

Of these compounds but few have sufficient importance to claim our attention. Compounds similar to the foregoing may be formed by other radicals than those here mentioned.

Ethyl-mercaptan, C_2H_5SH, is prepared by distilling calcium ethyl-sulphate with potassium hydrosulphide.

$$Ca(C_2H_5SO_4)_2 + 2KHS = CaSO_4 + K_2SO_4 + 2(C_2H_5SH).$$
Calcium Ethyl-sulphate.   Mercaptan.
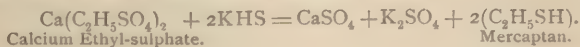
Mercaptan forms the upper layer of the distillate. Mercaptan has a powerful odor of garlic. It is a volatile liquid; sp. gr., 0.835. It burns with a blue flame. It is sparingly soluble in water, and dissolves in alcohol and ether. It forms, with metallic sodium or potassium, sodium or potassium mercaptid, C_2H_5SNa, C_2H_5SK, which are crystalline compounds soluble in water. Mercuric oxide reacts with mercaptan, evolving heat and forming a crystalline, inodorous compound, **mercuric mercaptid.** When a mixture of two mole-cules of mercaptan with one molecule of an aldehyde is treated with dry HCl, a **mercaptal** is produced, which may be regarded as an acetal whose oxygen is replaced by sulphur.

$$CH_3-C{\overset{O}{\underset{H}{\diagdown}}} + 2C_2H_5SH = \underset{CH_3}{\overset{H}{\diagup}}\!\!>C<\!\!{\overset{S-C_2H_5}{\underset{S-C_2H_5}{}}} + H_2O.$$

Aldehyde.　Mercaptan.　Mercaptal.
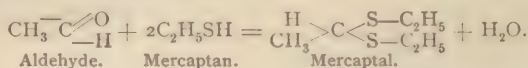
If this same reaction is produced with an acetone in place of an aldehyde, a **mercaptol** is produced, which differs from the mercaptal in that the alcoholic radical is substituted for the O atom of the ketone group CO.

$$CO{\overset{CH_3}{\underset{CH_3}{\diagdown}}} + 2C_2H_5SH = \underset{C_2H_5S}{\overset{C_2H_5S}{}}\!\!>C<\!\!{\overset{CH_3}{\underset{CH_3}{}}} + H_2O.$$

Acetone.　Mercaptan.　Mercaptol.
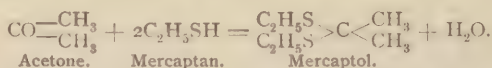
Mercaptol is a mobile liquid whose odor is not disagreeable. It boils at 80° C. (176° F.). When mercaptol is oxidized by potassium permanganate, it is converted into **sulphonal,** or diethyl-sulphon-dimethyl-methane, according to the following equation :

$$\underset{CH_3}{\overset{CH_3}{}}\!\!>C<\!\!{\overset{SC_2H_5}{\underset{SC_2H_5}{}}} + 2O_2 = \underset{CH_3}{\overset{CH_3}{}}\!\!>C<\!\!{\overset{SO_2C_2H_5}{\underset{SO_2C_2H_5}{}}}.$$

Mercaptol.　Sulphonal, or Diethyl-sulphon-dimethyl-methane.
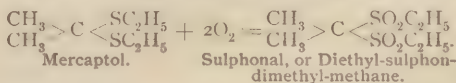
The relation of these bodies may be seen by reference to the following graphic formulæ :

$$\underset{CH_3}{\overset{H}{}}\!\!>C<\!\!{\overset{OC_2H_5}{\underset{OC_2H_5}{}}}$$
Acetal.

$$\underset{CH_3}{\overset{H}{}}\!\!>C<\!\!{\overset{SC_2H_5}{\underset{SC_2H_5}{}}}$$
Mercaptal.

$$\underset{CH_3}{\overset{CH_3}{}}\!\!>C<\!\!{\overset{SC_2H_5}{\underset{SC_2H_5}{}}}$$
Mercaptol.

$$\underset{CH_3}{\overset{CH_3}{}}\!\!>C<\!\!{\overset{SO_2C_2H_5}{\underset{SO_2C_2H_5}{}}}$$
Sulphonal.

$$\underset{CH_3}{\overset{C_2H_5}{}}\!\!>C<\!\!{\overset{SO_2C_2H_5}{\underset{SO_2C_2H_5}{}}}$$
Trional.

$$\underset{C_2H_5}{\overset{C_2H_5}{}}\!\!>C<\!\!{\overset{SO_2C_2H_5}{\underset{SO_2C_2H_5}{}}}$$
Tetronal.
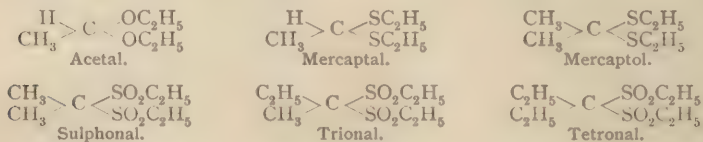
Sulphonal is a colorless, inodorous, practically tasteless, crystal-line body, melting at 125° C. (257° F.). It is soluble in fifteen parts of boiling water and in about 450 of cold. It is freely soluble in hot alcohol and less so in cold. Sulphonal is a very stable body, being unaffected by acids, alkalies, oxidizing agents, bromine, or

chlorine. Owing to its insolubility and stability, it does not present many characteristic reactions. Its solutions are neutral to test-paper, and are unaffected by barium nitrate or silver nitrate. It should burn away without residue when ignited with free access to air. When sulphonal is heated with potassium cyanide, the odor of mercaptan is evolved; and when the residue is dissolved in water, a drop of Fe_2Cl_6 gives a red color to the solution. The urine of patients taking considerable doses of sulphonal assumes a peculiar reddish-brown color, due to the presence of hematoporphyrin. This substance is most easily detected by the spectroscope. Sulphonal is used in medicine as a hypnotic, and has become official in the pharmacopeias of several European countries.

Sulphonic Acids.—A sulphonic acid is one which may be regarded as formed by replacing one of the hydroxyl groups in H_2SO_4 by a hydrocarbon radical.

In **sulphuric ethers** only the basic hydrogen is replaced.

By oxidation of ethyl-mercaptan, **ethyl-sulphonic acid** is formed.

$$2C_2H_5SH + 3O_2 = 2C_2H_5SO_2OH.$$
Ethyl-mercaptan.   Ethyl-sulphonic Acid.
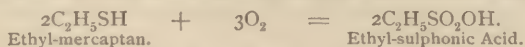
Sulphonic acids may be formed by acting directly upon unsaturated hydrocarbons with sulphuric acid.

$$H_2SO_4 + C_6H_6 = C_6H_5SO_2OH + H_2O.$$
Sulphuric Acid. Benzene. Benzene-sulphonic Acid. Water.

$$H_2SO_4 + C_6H_5CH_3 = C_6H_4CH_3SO_2OH + H_2O.$$
Toluene. Toluene-sulphonic Acid.
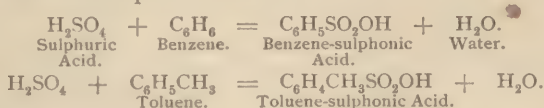
Sulphocarbolic Acid, Orthophenyl - sulphonic Acid.— $C_6H_4HO.SO_2OH$. If one part of crystallized carbolic acid be mixed with one part, by weight, of strong sulphuric acid, phenyl-sulphonic or sulphocarbolic acid is formed.

$$C_6H_5OH + H_2O_2SO_2 = C_6H_4OH.SO_2OH + H_2O.$$

If this solution be diluted with water and barium carbonate added in excess, a solution of barium sulphocarbolate is produced. From this the other salts may be prepared.

It occurs sometimes in small, deliquescent needles, but generally appears in the form of a heavy, red liquid of a syrupy consistency. It has an astringent taste and an odor resembling that of phenol. It is freely soluble in water, alcohol, and glycerin. It has been employed as an antiseptic, both internally and externally.

The acid has been sold under the names of **aseptol** and **sozolic acid**, and recommended as an antiseptic for internal use.

The sulphocarbolates of sodium and zinc are used as medicinal agents.

Sodii sulphocarbolas (U. S. P.) is a colorless, transparent, crystalline solid, with a cooling, saline, slightly bitter taste. It is soluble

35

in 4.8 parts of water and in 132 parts of alcohol. Its solutions give, with Fe_2Cl_6, a pale violet color.

Sozoiodol, di-iodo-para-phenolsulphonic acid, $C_6H_2I_2OH.-SO_2OH$, is a crystalline solid, occurring in acicular prisms, readily soluble in water, alcohol, and glycerin.

It is prepared by the action of a solution of iodide and iodate of potassium upon sulphocarbolate of potassium dissolved in dilute HCl. It has been used as a substitute for iodoform in surgical dressings. The sodium salt is recommended as a remedy for whooping-cough.

Salicyl-sulphonic acid, $C_6H_3 \begin{cases} OH \\ COOH \\ SO_2OH \end{cases}$, is formed by the action of strong sulphuric acid upon salicylic acid. It separates from the mixture in fine, white, needle-shaped crystals, very soluble in water. It is used as a delicate test for albumin in urine.

Calcium β-naphthol sulphonate has recently been introduced as an antiseptic under the name of **asaprol,** $Ca(C_{10}H_6SO_2OH)_2$. It occurs in acicular crystals, readily soluble in water and in alcohol. It has been used internally in doses of from 15 to 60 grs.

Alumnol, β-naphthol disulphonate of aluminum, $(C_{10}H_5-OH.(SO_3)_2)_3Al_2$, is a white powder, easily soluble in water and glycerin. It darkens on exposure to air.

It is prepared by heating β-naphthol with H_2SO_4 at 110° C. (230° F.). The resulting naphthol-disulphonic acid is converted into the barium salt, and this treated with aluminum sulphate to produce the aluminum salt.

It is used as an antiseptic and astringent.

Saccharin, glusidum (Br.), or **benzoyl-sulphonic imid,** $C_6H_4COSO_2NH$, is employed as a sweetening agent. Its sweetening power is 200 to 300 times that of sugar. The substance is usually prepared from toluene-sulphonic acid. It is a white powder, with an intense sweet taste and a fine almond odor. It is slightly soluble in water, forming a feebly acid liquid. It is more soluble in alcohol, glycerin, ammonia water, or in a solution of sodium bicarbonate. Saccharin has been largely recommended as a sweetening agent for use by diabetics, to avoid the use of sugar. It has, however, proven unsuitable for this purpose, owing to its disturbing effects upon the digestion. Owing to these effects, also, its use has been prohibited by statute in several European countries. It is employed to sweeten wines, and is sometimes used in pharmacy to sweeten elixirs, syrups, etc., and to mask the taste of the alkaloids and bitter principles.

Ichthyol, ammonium ichthyol-sulphonate, $C_{28}H_{36}S_3O_6(NH_4)_2$, is obtained by the distillation and purification of a pitch-like mineral

deposit. It is a dark-brown, pitch-like mass, having a disagreeable, tarry odor. The sodium, lithium, and iron salts have also been prepared, but the ammonium salt is the one generally used. It is soluble in water, glycerin, and most of the fixed oils.

Organo-metallic Compounds.—The hydrocarbon radicals can be made to combine with certain metals. They are usually obtained by the action of the iodide of an alcoholic radical upon the powdered metallic element in an atmosphere of H. They are substances which have been put to no use in the arts or in medicine, but are of interest principally in chemical synthesis. The hydrocarbon radicals also combine with ammonia, phosphin, arsin, and stibin. These compounds are similar to the ammonium compounds, which we shall study later. They are of no therapeutic interest.

The Nitro- Derivatives of the Hydrocarbons.—These are colorless liquids of ethereal odor, usually insoluble in water. They distil without decomposition, and sometimes explode on being quickly heated. They are distinguished from the ethers by not being saponified and by yielding amins on reduction, the N not being separated from the hydrocarbon radical. Thus:

$$CH_3NO_2 + 3H_2 = CH_3NH_2 + 2H_2O.$$
<div style="text-align:center">Nitro-methane. Methylamin.</div>
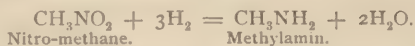
These nitro- compounds may be formed by treating the iodide of the hydrocarbon radical with silver nitrite, or, in some cases, by the direct action of nitric acid upon the hydrocarbon. This reaction, however, seldom takes place with the paraffins.

The constitution of the nitro- compounds is distinguished from the ethers in not being saponifiable, and from the fact that the nitrogen is not split off in their reduction, but remains bound to the carbon. From this we conclude that the nitrogen in them must be directly joined to the carbon, and not linked to it by oxygen, as in the case of nitrous ethers. The graphic formula of nitro-methane must be considered to be $CH_3-N\diagup_{O}^{O}$ or $CH_3-N\diagup_{O}^{O}$, while nitrous ether must be considered to be $CH_3-O-N=O$.

The nitro paraffins are not so numerous or important as those of the benzene or aromatic compounds, which will be considered later.

Nitrils, or Cyanides of Hydrocarbon Radicals.—Hydrocyanic acid yields two classes of derivatives by the exchange of its H atom for alcohol radicals, neither of which can be grouped among the ethers, since they do not go back into alcohols and hydrocyanic acid upon saponification, but decompose in another direction. These two classes of compounds are known as nitrils and iso-nitrils.

The nitrils are either colorless liquids which volatilize without decomposition, or solids of ethereal odor, lighter than air and relatively stable. They boil at about the same temperature as the corresponding alcohols. They are formed by heating the iodide of the radical with potassium cyanide, or by heating potassium ethyl-sulphate with potassium cyanide.

$$CH_3I + KCN = KI \quad + \quad CH_3CN$$
$$\text{Methyl-cyanide.}$$

$$\begin{matrix} KO \\ C_2H_5O \end{matrix} \Big\} SO_2 \; + \; KCN \; = \; C_2H_5CN \; + \; K_2SO_4$$
Potassium Ethyl-   Potassium   Ethyl-   Potassium
sulphate.   Cyanide.   cyanide.   Sulphate.
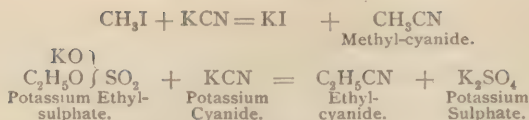
They may also be prepared by the dehydration of the ammonium salts of the corresponding acid, by means of P_2O_5 :

$$C_2H_3O_2NH_4 = CH_3CN + 2H_2O \qquad\qquad C_2H_3ONH_2 = CH_3CN + H_2O$$
Ammonium   Methyl-cyanide, or   Acetamid.   Methyl-cyanide, or
Acetate.   Aceto-nitril.   Aceto-nitril.
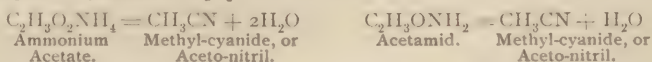
or by distilling the ammonium salts of monobasic acids, which contain one atom of carbon more than the alcohol which would correspond to the nitril desired. $C_2H_3O_2NH_4 = CH_3CN + 2H_2O$. As a consequence of these modes of formation, these compounds are termed the nitrils of the monobasic acids—that is, CH_3CN is named aceto nitril; C_2H_5CN, propio-nitril, or ethyl-cyanide. When these compounds are heated with acids, alkalies, or superheated steam, they break up into the acids from which they were originally prepared, and ammonia. Nascent H converts them into amins (see Aceto-nitril, Methyl-cyanide). CH_3CN is present in the products of the distillation of coal-tar. It is a colorless liquid, boiling at 82° C. (179° F.), is combustible, and miscible with water. The other nitrils of the higher hydrocarbon radicals are only of theoretical interest. Cyanides of the other series of hydrocarbons also exist.

Fulminate of mercury, $Hg(C_2N_2)O_2$, is obtained by warming alcohol with nitric acid and mercuric nitrate. It crystallizes in fine, silky prisms, which explode with great violence on being heated or struck. Fulminate of silver, having a similar composition, is even more explosive. These fulminating compounds are used in the manufacture of percussion caps.

The iso-cyanides, or iso-nitrils, or carbamins, are colorless liquids, easily soluble in alcohol and ether, but slightly soluble, or insoluble, in water. They have a feeble alkaline reaction, disagreeable odor, and poisonous properties. They are prepared by heating the iodides of the alcohol radicals with silver cyanide instead of potassium cyanide.

$$CNAg + C_2H_5I = AgI + \quad C_2H_5NC$$
$$\text{Ethyl-iso-cyanide.}$$
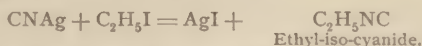
They may also be formed by the action of chloroform and an alcoholic solution of KOH upon the primary amins. The iso-nitrils differ from the nitrils by their behavior with water or dilute acids. When superheated with water or with acids in the cold, they split up into formic acid and an amin base. They do not decompose with alkalies, as nitrils do. Aceto-iso-nitril has the composition CH_3NC, while aceto-nitril has the composition CH_3CN—i. e., the N and not the C is tied to the CH_3 group in the iso-nitril. The iso-nitrils, therefore, are generally distinguished from the nitrils by reversing the positions of the C and N.

The following graphic formulæ will make this distinction clear :

$$CH_3$$
$$C \equiv N$$
Aceto-nitril.

$$CH_3$$
$$N \equiv C$$
Iso-aceto-nitril.

$$CH_3$$
$$CH_2$$
$$C \equiv N$$
Propio-nitril.

$$CH_3$$
$$CH_2$$
$$N \equiv C$$
Iso-propio-nitril
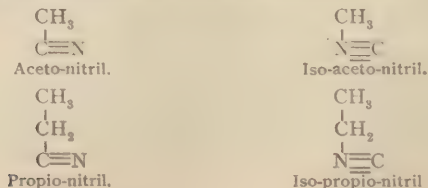
In most cases the cyanides of the hydrocarbon radicals—nitrils—can be converted into acids by heating them with KOH, HCl, or with H_2SO_4, diluted with its own volume of water, thus:

$$CH_3CN + 2H_2O = CH_3COOH + NH_3.$$
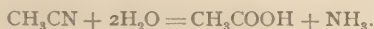
The relation of the derivatives or the various substitution products of the hydrocarbons may be illustrated by the following formulæ, derived from the first two members of the paraffin series:

	Methane, $C \equiv H_4$.	Ethane, $H_3 \equiv C—C \equiv H_3$.
Hydrocarbon.	Methane, $C \equiv H_4$.	Ethane, $H_3 \equiv C—C \equiv H_3$.
Haloid Ether.	Methyl-chloride, CH_3Cl.	Ethyl-chloride, $H_3 \equiv C—C \equiv H_2 \cdot Cl$.
Monohydric Alcohol.	Methyl-alcohol, H_3COH.	Ethyl-alcohol, $H_3C—CH_2OH$.
Dihydric Alcohol.		Ethylene Glycol, or Glycol, $HOH_2C—CH_2OH$.
Ether or Oxide.	Methyl-ether, $\begin{matrix} CH_3 \\ CH_3 \end{matrix} \Big\} O.$	Ethyl-ether, $\begin{matrix} C_2H_5 \\ C_2H_5 \end{matrix} \Big\} O.$
Compound Ether.	Methyl-nitrite, $CH_3—O—N{=}O.$	Ethyl-acetate, $C_2H_5—O—C_2H_3O.$
Aldehyde.	Formaldehyde, $H–C{\Large\langle}^O_H.$	Acetic Aldehyde, $H_3C—C{\Large\langle}^O_H.$
Ketone or Acetone.		Can exist only with three carbon atoms. Acetone, $H_3 \equiv C—\overset{\overset{\textstyle O}{\|}}{C}—C \equiv H_3.$
Acetal.	Methylal, $H_2{=}C{\Large\langle}^{O-CH_3}_{O-CH_3}$	Acetal, $H_2{=}C{\Large\langle}^{O-C_2H_5}_{O-C_2H_5}.$
Nitril.	Methyl-cyanide, $H_3C—CN.$	Propio-nitril, $H_3C—CH_2—C{=}N.$
Iso-nitril.	Methyl-carbamin, or Methyl-iso-cyanide, $H_3C—N \equiv C.$	Ethyl-carbamin, Ethyl-iso-cyanide, $H_3C—CH_2—N \equiv C.$
Monobasic Acid.	Formic Acid, $HCO . OH.$	Acetic Acid, $H_3C—CO.OH.$
Dibasic Acid.	Carbonic Acid, $O{=}C{\Large\langle}^{OH}_{OH}.$	Oxalic Acid, $\begin{matrix} CO.OH \\ | \\ CO.OH. \end{matrix}$

ORGANIC ACIDS.

The characteristic feature of an organic acid molecule is that it must contain the carboxyl group—COOH. The basicity of the acid will depend upon the number of these groups contained in its molecule. The organic acids partake of the general properties of the inorganic acids. They may be referred to the water type, and be considered as one or more molecules of water, in which one-half the hydrogen has been replaced by an organic compound radical containing oxygen—a negative radical—while the remaining hydrogen remains as replaceable or basic hydrogen.

$$H—O—H. \qquad H—O—C_2H_3O. \qquad \left. \begin{array}{l} H—O— \\ H—O— \end{array} \right\} C_4H_4O_4.$$
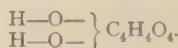
Water.   Acetic Acid.   Tartaric Acid.

As in inorganic acids, only those hydrogen atoms which are linked to the radical by oxygen are replaceable by a metal or basic radical. Organic acids may be formed by the oxidation of primary alcohols or aldehydes. The presence of an alkali favors the formation of an acid by oxidation.

Acids may be **monobasic, dibasic, tribasic,** etc., according as their molecules contain one, two, three, etc., carboxyl groups —COOH. Acids may also contain one or more hydroxyl groups, OH, which are not basic, because not immediately attached to or associated with CO, to form the carboxyl group. The hydrogen of these hydroxyl groups is called **alcoholic hydrogen,** to distinguish it from the other replaceable hydrogen, designated as **basic.** The number of hydroxyl groups in a molecule of either an alcohol or an acid is said to be its **atomicity.** It is evident that the atomicity of an acid may be greater than its basicity, when it is said to be an alcohol acid.

Lactic acid, $HOO\equiv C^-$ CH_2 $^-CH_2OH$, is a good example of a diatomic and monobasic acid.

The number of organic acids known is very large; only a few of the most prominent ones can, therefore, be mentioned here.

Of the many series of acids, the most numerous and important are those of the **acetic** or **fatty acid** series, corresponding to the marsh-gas series of hydrocarbons.

The acids of this series are obtained by the oxidation of the corresponding alcohols or aldehydes.

$$C_2H_5—O—H + O_2 = C_2H_3O—O—H + H_2O.$$
Alcohol.   Acetic Acid.
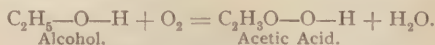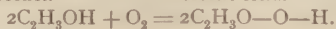
$$2C_2H_3OH + O_2 = 2C_2H_3O—O—H.$$
Aldehyde.   Acetic Acid.

They may also be obtained by the action of the alkaline hydroxides upon the cyanides of the radical of the next lower alcohol.

$$CH_3CN + KOH + H_2O = NH_3 + KC_2H_3O_2.$$
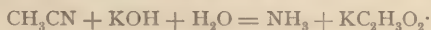
A few have been obtained by synthesis, starting with carbon monoxide.

$$CO + KOH = CHO\!-\!O\!-\!K.$$
<div align="center">Potass. Formate.</div>
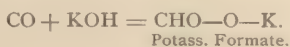
THE FATTY ACIDS, OR ALOPHATIC ACIDS.

The following is a list of the principal members of the fatty-acid series. General formula, $C_nH_{2n+1}COOH$. They are all saturated acids—*i. e.*, formed from saturated hydrocarbons.

Isomerism among the acids of this group is confined to the hydrocarbon radicals. Thus, there will be two isomeric acids of the formula C_3H_7COOH, because there are two propyl radicals.

	FUSING POINT.	BOILING POINT.	OCCURRENCE.
Formic acid, $CHOOH$, ...	4° C.	100° C.	Red ants, nettles.
Acetic acid, CH_3COOH, ...	17° C.	118° C.	Vinegar.
Propionic acid, C_2H_5COOH, . .	−21° C.	140° C.	Sweat, oxidation of oils.
Butyric acid, C_3H_7COOH, . . .	−20° C,	162° C.	Rancid butter.
Valerianic acid, C_4H_9COOH, . .	−16° C.	185° C.	Valerian-root.
Caproic acid, $C_5H_{11}COOH$, . . .	− 2° C.	205° C.	Rancid butter.
Enanthylic acid, $C_6H_{13}COOH$, .	−10° C.	224° C.	Oxidation of castor oil.
Caprylic acid, $C_7H_{15}COOH$, . .	14° C.	236° C.	Rancid butter, cocoanut oil.
Pelargonic acid, $C_8H_{17}COOH$, . .	18° C.	254° C.	Geranium-leaves.
Capric acid, $C_9H_{19}COOH$, . . .	30° C.	270° C.	Butter.
Lauric acid, $C_{12}H_{23}COOH$, . . .	43° C.	. . .	Bay-berries.
Myristic acid, $C_{13}H_{27}COOH$, . .	54° C.	. . .	Cocoanut oil, nutmeg, butter.
Palmitic acid, $C_{15}H_{31}COOH$, . .	62° C.	. . .	Palmitic acid, palm oil, animal fats.
Margaric acid, $C_{16}H_{33}COOH$, . .	60° C.	. . .	Synthesis.
Stearic acid, $C_{17}H_{35}COOH$, . . .	70° C.	. . .	Most solid animal fats.
Arachidic acid, $C_{19}H_{39}COOH$, . .	75° C.	. . .	Certain vegetable oils.
Behenic acid, $C_{21}H_{43}COOH$, . .	76° C.	. . .	" " "
Hyenic acid, $C_{24}H_{49}COOH$, . .	77° C.	. . .	Fat of hyena.
Cerotic acid, $C_{26}H_{53}COOH$, . . .	80° C.	. . .	Beeswax.
Melissic acid, $C_{29}H_{59}COOH$, . .	90° C.	. . .	"

MONATOMIC ACIDS.

$$C_nH_{2n}O_2 = C_nH_{2n+1}COOH.$$

Of the large number of acids in this group, we shall notice formic, acetic, butyric, valerianic, palmitic, and stearic.

Formic acid, $CHO-O-H$, is a colorless liquid, of a very acid reaction and sharp, pungent odor. It boils at about 100° C. (212° F.), and solidifies at about 0° C. (32° F.). It exists ready formed in the red ant, stinging-nettle, and pine-needles. It acts as a reducing agent, reducing silver and mercury salts and depositing the metals. It is used in silvering glass, to reduce the silver which deposits upon the walls of the containing vessel. The best method of obtaining it is by heating to about 100° to 110° C. (212° to 230° F.) pure anhydrous glycerin and dry oxalic acid, adding more oxalic acid from time to time, and continuing the distillation. Carbon monoxide dissolved in potassium hydroxide yields some potassium formate.

Acetic acid, C_2H_3O-O-H, occurs in the form of acetates in some vegetable and animal fluids. It is usually obtained by the fermentation of saccharine fluids after they have undergone the alcoholic fermentation, or by the dry distillation of wood, starch, etc.

In distilling wood, gases, methyl-alcohol (wood-spirit), acetic acid, water, creosote, and tar are obtained. The liquid portion is distilled at a gentle heat, when the alcohol is separated. The remaining liquid, containing the acetic acid, is saturated with sodium carbonate, evaporated to dryness, and heated to 250° to 350° C. (482° to 662° F.) to char the tarry matters. The residue, containing sodium acetate, is dissolved in water, filtered, evaporated, and allowed to crystallize out. If the free acid is desired, the residue, after carbonizing, is distilled with a slight excess of sulphuric acid. This gives a colorless, strongly acid, sour-smelling liquid, which crystallizes at about 17° C. (63° F.) and is known as glacial acetic acid.

Acetic acid, when applied to the skin, blisters and causes considerable pain. When not too strong it acts as a styptic. It is soluble in water, alcohol, and ether in all proportions. It dissolves resins, camphor, fibrin, and coagulated albumin. It precipitates mucin, and is used to separate this body from its solutions. It is also used, with the aid of heat, as a test for albumin ; but care is taken not to add too much, as it dissolves the albumin. Under the action of chlorine, acetic acid furnishes a series of chlorine substitution compounds, in which the chlorine is substituted for the hydrogen of the radical ; thus we have monochlor-, dichlor-, and trichlor-acetic acids.

$$C_2H_2ClO_2H, \quad C_2HCl_2O_2H, \quad \text{and} \quad C_2Cl_3O_2H.$$
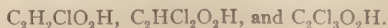
The last of these is mentioned elsewhere as a test for albumin in urine.

Vinegar.—This name is given to the mixture obtained by the fermentation of wine, cider, whisky, molasses, infusion of malt, etc., under the influence of the growth of **mycoderma aceti**, and should contain at least four per cent of acetic acid.

$$C_2H_5OH + O_2 = C_2H_3O—O—H + H_2O.$$

Alcoholic fermentation always precedes the acetous.

As vinegar always contains more or less of this ferment, called mother of vinegar, it is customary to add some of this fluid to start the process. The fermentation takes place slowly, in vats or casks, because of the small amount of surface presented to the air. The process is rendered very much more rapid by allowing the fluid to trickle over beech-wood shavings or chips, placed upon trays or in perforated barrels, so as to expose a large surface to the air. After having passed over the shavings four times, it will be found to be pretty thoroughly acetified. The temperature should be kept at about 25° C. (77° F.).

The vinegar of the market is frequently adulterated with—1, water; 2, mineral acids, especially sulphuric; 3, metallic impurities, as arsenic, lead, zinc, copper, and tin; 4, wood-vinegar; 5, organic substances, such as coloring matters, capsicum, etc.

The addition of water can only be detected by the estimation of the percentage of acetic acid.

The most objectionable adulterant is sulphuric acid. The simplest method of detecting free mineral acids is to evaporate a portion of the vinegar to dryness; heat the residue to dull redness for some time, to convert the acetates of the alkaline metals into carbonates, which salts can easily be detected by their effervescence with hydrochloric acid. If any free mineral acid existed in the vinegar, it would expel the acetic acid from the alkali metals and convert them into inorganic salts, which remain unchanged on ignition.

Another test for mineral acids is methyl-violet. Two or three drops of a solution of this compound (0.1 to 100) are added to 25 c.c. of vinegar. If 0.2 per cent. of any mineral acid be present, the color is blue; if 0.5 per cent., blue-green; if 1 per cent., green.

A simple test for sulphuric acid is to evaporate a portion to dryness in a white porcelain dish, with a little cane-sugar. Near the end of the process, the residue becomes black by the charring of the sugar by the acid. A small quantity of sulphuric acid is sometimes added to make the vinegar keep. The poisonous metals likely to be found are mercury (corrosive sublimate), copper, arsenic, and lead. These

metals may be detected by saturating the vinegar with hydric sulphide, or by separate tests for each. Burned sugar, capsicum, etc., may be detected by taste or odor in the residue left on evaporation. The acetates are eliminated from the body as carbonates.

Propionic acid, C_2H_5COOH, is a colorless liquid, boiling at 140° C. (284° F.). It resembles acetic acid in odor and taste. Its salts are soluble and crystallizable. It is best prepared by heating ethyl-cyanide—propio-nitril—with KOH until the odor of ether has disappeared, when the propionate of potassium is obtained. The acid may be obtained by decomposing this salt with H_2SO_4. The acid is produced during the putrefaction of various organic bodies, and in the destructive distillation of wood and of resin.

Butyric Acid.—$C_4H_7.O.O-H$. This acid is found, with other fatty acids, in butter, human perspiration, feces, flesh-juice, and in some beetles. It exists in butter as a glycerid or glyceric ether. Pathologically, it appears in a free state in urine, blood, and ovarian cysts, and in the sputa of gangrene of the lung and bronchiectasis. It also appears in the intestinal contents as the result of a secondary fermentation of saccharine articles of food.

It is best prepared by maintaining at a temperature of 35° to 40° C. (95° to 104° F.) a solution of sugar containing lime or chalk and sour milk or rotten cheese. A mixture of ten parts of sugar, one part of cheese, and ten parts of chalk answers very well. Lactate of calcium is first produced, which afterward changes, under the influence of the ferment of cheese, into butyrate of calcium. The solution should remain alkaline or neutral. Carbon dioxide and hydrogen are set free. When the fermentation is finished, thirty or forty parts of crystallized sodium carbonate are added, and the mixture warmed and filtered. The filtrate is evaporated nearly to dryness, and hydrochloric or sulphuric acid added, which sets free the butyric acid as an oily layer, which may be purified by distillation. It boils at 162° C. (323° F.). It is a colorless liquid, with the characteristic penetrating odor of rancid butter. It is soluble in pure water, but separates if soluble salts are added to the solution. It is soluble in alcohol, oils, and ether. The butyrates are all soluble in water.

Isobutyric acid, an isomer of the foregoing, is obtained by the oxidation of secondary or isobutylic alcohol. The following graphic formulæ show the constitution of these bodies:

Butylic Alcohol.   Butyric Acid.

Isobutyl Alcohol.

Isobutyric Acid.
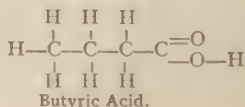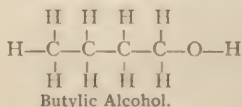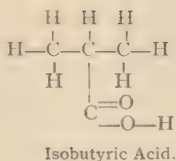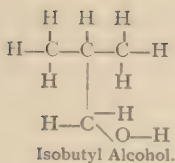
Valeric or Valerianic Acids.—C_5H_9COOH. There are four possible isomeric valerianic acids, corresponding to the four amyl-alcohols. Three are known.

Normal valerianic acid, $CH_3CH_2CH_2CH_2COOH$, occurs in angelica and valerian roots, and its ammonium salt is formed by the putrid fermentation of albuminoid matters. It is sometimes found in the urine and feces in small-pox, typhus fever, and yellow atrophy of the liver. It is obtained by distilling the powdered valerian root with water. It is best prepared by the oxidation of amylic alcohol. A mixture of one part of amyl-alcohol and four parts of concentrated sulphuric acid is run slowly into a retort containing four parts of water and five of potassium dichromate. The first product is valeraldehyde, which distils over. By elevating the beak of the retort so as to run the aldehyde back into the oxidizing mixture, it is changed into valerianic acid. The mixture is finally distilled, the distillate neutralized with sodium carbonate, evaporated, and decomposed with sulphuric acid.

Valerianic acid is a thin, oily liquid, boiling at 175° C. (347° F.) and possessing a sour, old-cheese odor. The most of the valerianates are soluble in water, and, when moist, smell like the acid.

Valerianates of ammonium, bismuth, caffeine, quinine, iron, and zinc are used in medicine.

Palmitic acid, $C_{15}H_{31}COOH$, is the first of the fatty acids, properly so called, which occurs in the animal fats and forms true soaps with the alkalies. On a large scale, palmitic acid is made from palm oil. The oil is decomposed in a still by superheated steam at a temperature of about 315° C. (599° F.). When the condensed liquid is run out into receivers, it separates into two layers, the upper of which consists of the free fatty acids. On cooling, palmitic acid forms a white, crystalline solid, and is used for making candles. It may also be prepared on a smaller scale by boiling palm oil with potassium carbonate, which converts it into potassium palmitate and oleate. On decomposing these salts with dilute H_2SO_4, the mixture of palmitic and oleic acids separates. This is washed, dried, and dissolved in hot alcohol, from which the palmitic acid crystallizes, leaving the oleic acid in solution. Palmitic acid crystallizes in needles which fuse at 62° C. (143.6° F.). It decomposes on distilla-

tion, except in the presence of water. **Adipocere**, a wax-like mass which is sometimes left when animal bodies decompose in the earth, is a mixture of the palmitates of calcium, potassium, and occasionally ammonium. This substance is formed especially in bodies buried in damp soil, or in bodies which remain in the air some time after death. It is found to occur in muscles in a definite order. The amount of adipocere present is a good gage of the time a body has been dead. Palmitic acid is insoluble in water, and is soluble in alcohol and ether.

Stearic acid, $C_{17}H_{35}COOH$, exists as a glycerid in all solid animal fats, and in many oils. It may be prepared from tallow by boiling it with potassium carbonate, decomposing the resulting soap with HCl, separating the fatty acids, drying, and dissolving in a large quantity of hot alcohol. Afterward, the hot solution in alcohol is partly precipitated by a strong solution of barium acetate. The precipitate is decomposed with HCl, when stearic acid precipitates. This is collected, washed, dried, and recrystallized from alcohol. Stearic acid is a white, crystalline solid of the same sp. gr. as water, fusing at $69°$ C. ($156.2°$ F.). Stearic acid exists in fats as stearin, mixed with palmitin and olein. These glycerids may be saponified by superheated steam. Stearic acid is insoluble in water, but soluble in alcohol and ether. It burns with a luminous flame, and is much employed in the manufacture of candles and soaps. The so-called **stearine candles** are a mixture of palmitic and stearic acids. Both palmitic and stearic acids are found in the free state in the intestines during the digestion of fats, a portion of which are decomposed by the action of the pancreatic juice, and sometimes found as white masses in the stools.

Margaric acid, $C_{16}H_{33}COOH$, is synthetically obtained. The substance formerly known by this name, and supposed to exist in natural fats under the name of margarin, is a mixture of palmitin and stearin.

Oleic acid, acidum oleicum (U. S. P., Br.), $C_{17}H_{33}COOH$, belongs to the acrylic series, and not to the acetic series. The general formula of this series is $C_nH_{2n-1}COOH$. Oleic acid occurs as triolein in most fats and oils. It is prepared by boiling olive oil with potassium carbonate, decomposing the solution with HCl, collecting the oily layer which separates, and heating it with litharge to $100°$ C. ($212°$ F.) for some hours, when a mixture of oleate, palmitate, and stearate of lead is formed. The oleate is dissolved out of the mixture with ether, and the solution shaken with HCl to precipitate the lead. The ether is then distilled away, and the impure oleic acid is dissolved in ammonia and precipitated by $BaCl_2$. The barium

oleate is recrystallized from alcohol, and finally decomposed by tartaric acid. Oleic acid is a yellowish or brownish-yellow, oily liquid, having a peculiar, lard-like odor and taste, and becomes darkened on exposure to the air. Its sp. gr. is about 0.900. It is insoluble in water, soluble in alcohol, chloroform, benzene, oil of turpentine, and other fixed and volatile oils. At about 4° C. (39° F.) it becomes semisolid, and at lower temperatures a whitish, solid mass. It can not be distilled without decomposition, except in the presence of steam. When heated to about 95° C. (203° F.) it begins to decompose, giving off acrolein vapors. Its alcoholic solution has a faintly acid reaction upon litmus paper. Equal volumes of oleic acid and alcohol should give a clear mixture at ordinary temperatures, but if any oil be present it separates in drops. Oleic acid is a by-product in the manufacture of candles. The commercial acid absorbs oxygen readily when exposed to the air. By the action of nitrous acid, or nitrous fumes, oleic acid is converted into isomeric elaidic acid, a solid, crystalline acid, fusing at 45° C. (113° F.). This acid is formed in the preparation of **unguentum hydrargyri nitratis** (U. S. P.). The nitrous fumes given off convert the oleic acid of the oil or lard into elaidic acid, which exists in the ointment in combination with mercury.

ACIDS DERIVED FROM GLYCOL.

The glycols, it will be remembered, are diatomic alcohols, and by oxidation may give rise to two series of acids, thus:

$$C\begin{matrix}-OH\\=H_2\end{matrix}$$
$$\begin{matrix}|\\C\end{matrix}\begin{matrix}=H_2\\\backslash OH\end{matrix}$$
Ethyl-glycol.

$+ O_2 =$

$$C\begin{matrix}-OH\\=O\end{matrix}$$
$$\begin{matrix}|\\C\end{matrix}\begin{matrix}=H_2\\\backslash OH\end{matrix}$$
Glycolic Acid.

$+ H_2O$

and

$$C\begin{matrix}-OH\\=H_2\end{matrix}$$
$$\begin{matrix}|\\C\end{matrix}\begin{matrix}=H_2\\\backslash OH\end{matrix}$$
Ethyl-glycol.

$+ 2O_2 =$

$$C\begin{matrix}-OH\\=O\end{matrix}$$
$$\begin{matrix}|\\C\end{matrix}\begin{matrix}=O\\\backslash OH\end{matrix}$$
Oxalic Acid.

$+ 2H_2O$
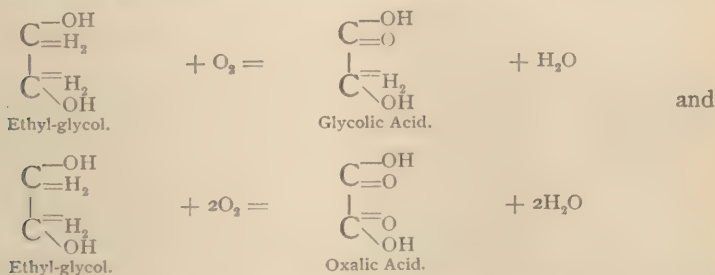
The other glycols can in the same manner furnish two series of acids: the one diatomic and monobasic, and known as the **lactic acid series**; and the other dibasic, and known as the oxalic (or succinic) series. These glycols and acids are as follows:
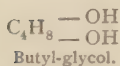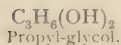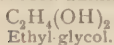
GLYCOL SERIES.	LACTIC SERIES.	OXALIC SERIES.
$C_2H_4(OH)_2$ Ethyl-glycol.	$CH_2 {-COOH \atop -OH}$ Glycolic Acid.	CO.OH CO.OH Oxalic Acid.
$C_3H_6(OH)_2$ Propyl-glycol.	$C_2H_4 {-COOH \atop -OH}$ Lactic Acid.	$CH_2 {-COOH \atop -COOH}$ Malonic Acid.
$C_4H_8 {-OH \atop -OH}$ Butyl-glycol.	$C_3H_6 {-COOH \atop -OH}$ Oxybutyric Acid.	$C_2H_4 {-COOH \atop -COOH}$ Succinic Acid.
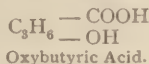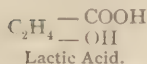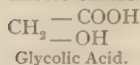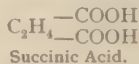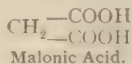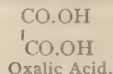
DIATOMIC MONOBASIC ACIDS.

But two acids of this group are worthy of special mention—viz., **glycolic** and **lactic acids**.

Glycolic acid, $CH_2\text{-}O\text{-}H \atop CO\text{-}O\text{-}H$, is found in unripe grapes and in the green leaves of the Virginia creeper. When pure, it forms large, regular crystals, which deliquesce in moist air and melt at 79° C. (174° F.).

Lactic Acid, Hydroxy-propionic Acid, Acidum Lacticum (U. S. P., Br.).—There are at least three isomeric lactic acids known, and a fourth has been described. There are but two possible graphic formulæ representing hydroxy-propionic acid—viz., $CH_2OH \atop CH_2 \atop COOH$ and $CH_3 \atop CHOH \atop COOH$. The first of these is called **ethylene-lactic acid,** or **hydracrylic acid,** and those of the second formula are called **ethylidene-lactic acids.** Ethylene-lactic acid is not found in the human body, and little is known of it. There are three lactic acids corresponding to the second formula, differing principally in physical properties : the first optically inactive, the second dextrorotatory, and the third levorotatory. The optically inactive ethylidene-lactic acid is the ordinary fermentation acid, and is probably a mixture of equal molecules of the other two isomerides.

This lactic acid is the acid of sour milk and sour cabbage, and is produced by a special ferment, the **bacterium lactis,** or **lactic ferment.** It is found in small quantities in the gastric juice, urine, and intestinal juice.

It is produced on a large scale by the lactic fermentation of cane-sugar and glucose. Flour is first treated with dilute sulphuric acid, to convert the starch into glucose ; the free acid is then neutralized with milk of lime. To this is then added sour milk, and it is allowed to ferment, care being taken to stop the process before butyric acid fermentation sets in, by heating the mixture to boiling. The hot solution of calcium lactate is separated by filtration, evaporated down, and allowed to crystallize. From this salt the acid may be obtained by saturation with sulphuric acid. It has been prepared synthetically by the oxidation of propyl-glycol. A solution containing seventy-five per cent. of the acid is official in the U. S. P. It is a colorless, syrupy, odorless, very acid liquid, freely miscible with water, alcohol, and ether. It has been used to check lactic and butyric fermentation in the intestinal tract, as an excess of this acid prevents the further growth of the ferment. It has been prepared synthetically by heating aldehyde with hydrocyanic acid. It is used in the preparation of syrup of the lactophosphates (U. S. P.).

Ferrous Lactate, Ferri Lactas (U. S. P.).—$Fe(C_3H_5O_3)_2$.-$3H_2O$. It occurs in pale, greenish-white, odorless, crystalline crusts or grains, permanent in the air and soluble in water.

Strontium lactate, strontii lactas (U. S. P.), $Sr(C_3H_5O_3)_2$.-$3H_2O$, also used in medicine, occurs as a white, granular powder, soluble in water.

Dextrorotatory lactic acid, sarcolactic acid, or **paralactic acid,** is isomeric with the above. It has not been prepared synthetically, but is characteristic of muscle-juice, and gives to muscular tissue its acid reaction. It occurs in the blood, especially after active muscular exercise. It is found in the urine, and in increased amount after violent muscular exertion, and very strikingly after extirpation of the liver in birds and frogs. It has been found in the fluid of ovarian cysts and in other pathological fluids. It is found in extracts of beef, and may be prepared from Liebig's extract after precipitating with alcohol, acidifying with H_2SO_4, and shaking the filtrate with excess of ether, which dissolves it. On evaporating the ether, dissolving the residue in water, and precipitating with zinc acetate, the zinc salt is obtained. By recrystallizing this salt, suspending it in water, and decomposing with hydrosulphuric acid gas, the acid is obtained in solution. It may be separated by dissolving it out with ether. The acid thus obtained is similar in most of its physical and chemical properties to ordinary lactic acid. It is dextrorotatory, however, while ordinary lactic acid is optically inactive.

Sarcolactic acid obtained from muscular tissue is said to contain another acid in small quantities, known as ethylene-lactic acid.

Dead muscle has an acid reaction, which is greater as *rigor mortis* appears. During life the acidity increases with active contraction and diminishes with rest. The acid is probably produced by the decomposition of the muscular tissue during contraction, although some have claimed that the acidity is due to acid phosphates produced from the phosphates of the tissue during muscular action, while others have thought that the lactic acid is due to the transformation of the glycogen usually found in muscle.

Lymphatic, thymus, and thyroid tissues are alkaline during life, but become rapidly acid after death, from the presence of sarcolactic acid.

Levorotatory lactic acid, the third isomeric ethylidene-lactic acid, is produced by the fermentation of cane-sugar by a special ferment. Very little is known about its properties.

Tests for Lactic Acids.—All of these acids give an intense yellow color with a very dilute solution of ferric chloride.

If to about 10 c.c. of water 2 drops of carbolic acid and 1 drop of ferric chloride solution be added, and to this violet solution a mere trace of lactic acid be added, it instantly changes to yellow. (Uffelmann.)

This test will show 1 part of the acid in 10,000 parts of water.

Oxybutyric acid is found in the urine of diabetics, and is mentioned in the chapter on the urine.

DIATOMIC DIBASIC ACIDS.

Oxalic Acid.— $\dfrac{\text{C.OO–H}}{\text{CO.O–H}} = H_2C_2O_4.$ This important acid occurs in many plants (Oxalis, Rumex, Rheum) as acid calcium or potassium oxalates. Calcium oxalate is also found in the urine.

Oxalic acid is easily obtained by acting upon many organic substances with oxidizing agents. Glycol and glycolic and acetic acids may be made to yield it. It is best prepared from the carbohydrates (sugar, starch, etc.), by treating them with strong nitric acid, or by fusing with caustic potash. Commercial oxalic acid is prepared by fusing sawdust with a mixture of caustic soda and potash, and treating the oxalates thus formed with hydrochloric acid. The acid crystallizes in colorless prisms with two molecules of water, which they lose at 100° C. (212° F.). It is soluble in eight parts of cold water and in alcohol. On heating the acid, it is resolved into carbon monoxide, dioxide, water, and formic acid. Strong oxidizing agents

convert it into carbon dioxide and water. It is a strong dibasic acid, and forms both acid and neutral salts with most of the metals.

Oxalic acid easily oxidizes into CO_2 and H_2O. This may be effected by chromic acid, potassium permanganate in presence of dilute H_2SO_4, and even on exposure of its watery solution to air and sunlight. Dehydrating agents, as H_2SO_4 and H_3PO_4, decompose it into CO, CO_2, and H_2O. Oxalic acid resembles magnesium sulphate in appearance, and has been taken by mistake for this salt.

Oxalic acid is both a corrosive and systemic poison. Death has followed the use of ʒj (4 gm.), but persons have recovered after taking much larger doses. Much will depend upon the concentration of the poison. When the solid or a strong solution is taken, its local effect is most marked, and death may occur within half an hour. If recovery takes place, owing to prompt treatment, the after-effects will be those of any of the corrosive poisons. If the acid is taken in dilute solution, the local effect is much less, or almost wanting. In such cases the poison is absorbed, and acts as a systemic poison. Vomiting and cramps are usually, though not always, present. The soluble salts of oxalic acid are almost as poisonous as the acid, but do not have the same local corrosive effect.

The treatment should be prompt and judicious. It is important to learn, if possible, the condition in which the acid was swallowed. If in concentrated solution or as the solid, the stomach-pump, or even the stomach-tube, should not be used. If taken diluted, and the burning epigastric pain is not too severe, the soft stomach-tube may be used with care, washing the stomach out thoroughly with lime-water, followed with pure water. If lime-water is not procurable, milk of magnesia or a solution of magnesium sulphate (Epsom salts) may be used. If it is deemed unsafe to use the tube, vomiting may be induced, and the stomach washed out by giving a lukewarm mixture of equal quantities of lime-water and sink- or well-water.

Tests for Oxalic Acid.—Calcium chloride gives, even in very dilute, neutral, or alkaline solutions, a fine, white, heavy precipitate. The precipitate is soluble in HCl, but not in acetic acid.

Silver nitrate gives a white precipitate, soluble in HNO_3 and in NH_4OH.

Lead acetate gives, in not too dilute solutions, a white precipitate, soluble in HNO_3, but not in acetic acid.

It discharges the color of $K_2Mn_2O_8$ in presence of dilute H_2SO_4.

Succinic Acid.—$C_2H_4 {\displaystyle <} {COOH \atop COOH}$. This acid is found ready formed in amber and some other resins, in several plants, in the spleen, in thymus and thyroid glands, in hydrocephalic and hydrocele fluids.

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It is obtained in small quantities in the alcoholic fermentation of sugar and in the putrefaction of proteids.

It may be prepared by the spontaneous fermentation of tartaric or malic acids. It is one of the products of alcoholic fermentation of sugar, and may be prepared by the action of reducing agents on malic and tartaric acids. It may be obtained in quantity by the dry distillation of amber; the aqueous portion of the distillate is heated to boiling, and filtered; on cooling, crude succinic acid crystallizes out. Succinic acid crystallizes in monoclinic prisms, melting at 180° C. (356° F.), and decomposing into water and succinic anhydride at 235° C. (455° F.). It is soluble in twenty-three parts of cold water, and very freely soluble in hot water. By adding neutral solution of ferric chloride to a soluble succinate, a brown, gelatinous, ferric succinate is produced; this reaction is used as a qualitative test for the acid. The succinates of the alkaline metals are soluble; those of the other metals are either slightly soluble or insoluble.

There are two isomeric succinic acids, but isosuccinic acid is unimportant.

TRIATOMIC DIBASIC ACIDS.

The simplest acid of this class must contain three carbon atoms, and in that case may be regarded as being derived from the triatomic alcohol, glycerin. By the oxidation of glycerin we may form two acids, thus:

Glycerin. Glyceric Acid. Tartronic Acid.
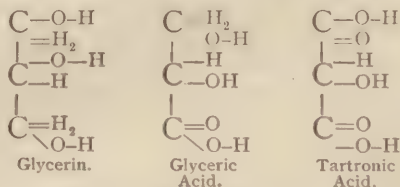
These acids are not of sufficient importance to demand a separate description.

Malic acid, oxysuccinic acid, $C_2H_3 \begin{cases} CO\ O-H \\ O-H \\ CO\ O-H \end{cases}$, may be

viewed as a homologue of tartronic acid, or as derived from succinic acid. It occurs in many acid fruits, as cherries, apples, raspberries, gooseberries, rhubarb (stalks and leaves), unripe mountain-ash berries, unripe grapes, and quinces. It is best prepared by nearly saturating the boiled and filtered juice of the berries of the mountain-ash with milk of lime. On continued boiling, calcium malate, $CaC_2H_3(HO)$-

$(COOH)_2.H_2O$, separates as a crystalline powder, from which the acid may be obtained by treatment with dilute nitric acid. Malic acid crystallizes in groups of small, colorless, deliquescent crystals. It melts at 100° C. (212° F.), and decomposes at 150° C. (302° F.). Putrefactive ferments convert malic into acetic, succinic, butyric, and carbonic acids.

There are three isomeric malic acids possible, of which two are known. The alkaline malates are soluble ; other malates are slightly soluble or insoluble ; all are crystalline.

The malates are easily oxidized, and are converted in the animal body into carbonates.

TETRATOMIC DIBASIC ACIDS.

Tartaric acid, acidum tartaricum (U. S. P., Br.),

$$\begin{array}{cccc} O & H & H & O \\ \| & | & | & \| \\ C{-}C{-}C{-}C \\ | & | & | & | \\ O & O & O & O \\ H & H & H & H \end{array}$$
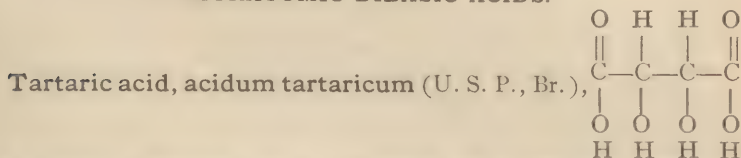
is a dibasic, tetratomic acid. (Compare the formulæ of succinic, malic, and tartaric acids.) Four isomeric tartaric acids are known : two of which—dextro- and levotartaric acids—are optically active ; and two—racemic and mesotartaric acids—are optically inactive. Ordinary or **dextrotartaric acid** is found in many fruits, particularly in ripe grapes, as acid potassium tartrate (**cream of tartar**), which, during the fermentation of the must, is deposited, mixed with yeast, coloring matter, calcium tartrate, etc., as a brown crust, or deposit, known as crude **argol**. Tartaric acid is prepared from argol by first treating it with hot water, filtering, decolorizing with animal charcoal, converting the acid potassium tartrate into calcium tartrate by the addition of milk of lime, then decomposing this with sulphuric acid. Tartaric acid is thus obtained in solution, and may easily be separated by crystallization. Tartaric acid is usually made in the same factories where **cream of tartar** is prepared in large quantities. It usually occurs in beautiful, oblique prisms, permanent in the air, soluble in one-half their weight of water, or in 2.5 parts of alcohol, and insoluble in ether. When heated, it melts at 135° C. (275° F.), and forms metatartaric and pyrotartaric acids and tartaric anhydride, $C_4H_4O_5$. At a higher temperature it decomposes, with a burnt-sugar odor.

Tartaric acid has a strong, acid taste. It precipitates calcium in neutral or alkaline solutions, but not in strongly acid solutions. Ammonium salts prevent this precipitation. Heated with hydriodic acid and phosphorus, tartaric is first changed into malic and then into succinic acid.

The principal tartrates are the neutral and acid potassium tartrates, sodio-potassium tartrate (**Rochelle salt**) and **tartar emetic,** or antimonyl potassium tartrate, all of which are mentioned in another place. Ferro-potassium tartrate and ferro-ammonium tartrate are also used in medicine. They both belong to the class of substances known as **scale compounds**—*i. e.*, compounds which do not crystallize readily, and are prepared by spreading the material, evaporated to a syrup, upon plates of glass to dry, and then scraping off the thin scales. The above-mentioned compounds occur in the form of garnet-red scales, slightly deliquescent, very soluble in water, but insoluble in alcohol. Tartaric acid is used in making effervescing drinks, in calico printing, and by confectioners, to prevent the crystallization of the sugar. When taken in too large quantities, it acts as an irritant poison. One ounce has caused death.

When taken in not too great quantity, its salts are oxidized to car-bonates ; but if taken in very large quantity they may escape complete destruction and may appear in the urine and perspiration. It is, therefore, not so easily oxidized as malic, succinic, and some other organic acids.

TETRATOMIC TRIBASIC ACIDS.

Citric Acid, Acidum Citricum (U. S. P., Br.).—

$$CH_2CO.OH$$
$$CH.CO.OH = C_6H_5O_4(OH)_3$$
$$CH.(OH)CO.OH$$
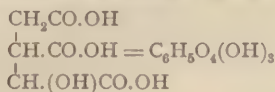
This acid occurs in the juice of lemons, limes, currants, gooseberries, beet-roots, and other fruits. It is manufactured on a large scale from lemon-juice, or lime-juice, which is clarified by boiling it with albumin, and then saturated, while hot, with powdered chalk or milk of lime. The precipitated calcium citrate is decomposed by an equivalent quantity of sulphuric acid, and filtered from the resulting gypsum. On evaporating the filtrate the acid crystallizes out in large, transparent, rhombic prisms, having an agreeable, sour taste, and containing one molecule of water of crystallization. The acid melts between 135° and 152° C. (275° and 305.6° F.), and is readily soluble in water and alcohol. At 175° C. (347° F.) the acid loses water and is converted into **aconitic acid,** $C_6H_3O_3(OH)_3$.

Solutions of citric acid soon develop mould, and are thereby decom-posed. Citric acid forms three classes of well-defined salts with the

metals. Citrates of the alkaline metals are soluble in water. The citrates are decomposed into carbonates in the body, and, in case of the citrates of the alkalies, are eliminated by the kidneys as carbonates; hence, these citrates are frequently prescribed in acid conditions of the urine. Citric acid is not known to exert any injurious action upon the economy, even in considerable quantities.

Citrates of bismuth, iron, iron and ammonium, iron and quinine, iron and strychnine, lithium, potassium, bismuth and ammonium, solution of magnesium citrate, and syrup of citric acid are official. When boiled with excess of lime-water, citric acid precipitates basic calcium citrate. This distinguishes it from oxalic and tartaric acids.

Meconic acid, acidum meconicum (Br.), $C_4OH(CO.OH)_3$, is found in opium, in combination with the alkaloids. It may be prepared from opium by digesting it with hot water, neutralizing with $CaCO_3$, and then precipitating with $CaCl_2$. The precipitate hydrocalcium meconate, $HCaC_7HO_7$, may be dissolved in hot dilute HCl and the acid crystallized out. The acid occurs in crystalline plates, dissolving rather sparingly in cold, but easily in hot water and alcohol. Ether dissolves it but sparingly. It has an astringent taste. Solutions of meconic acid give a blood-red color with ferric chloride, which is not discharged by $HgCl_2$ or dilute acids, but is discharged by stannous chloride and sodium hypochlorite.

The relation of the foregoing alcohols, aldehydes, and acids will be seen by the following graphic formulæ :

$$
\begin{array}{c}
C\diagup\!\!\!\diagdown\!\!\text{OH} \\
\text{H}_2 \\
C=\text{H}_2 \\
C\diagup\!\!\!\diagdown\!\!\text{H}_2 \\
\text{OH}
\end{array}
$$
Propene Glycol.

$$
\begin{array}{c}
C\diagup\!\!\!\diagdown\!\!\text{OH} \\
\text{H}_2 \\
CH_2 \\
C\diagdown\!\!\text{O} \\
\text{OH}
\end{array}
$$
Ethylene-lactic Acid.

$$
\begin{array}{c}
C\equiv H_3 \\
C\diagup\!\!\text{H} \\
\diagdown\!\!\text{OH} \\
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Ethylidene-lactic Acids.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\text{OH} \\
C=\text{H}_2 \\
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Malonic Acid.

$$
\begin{array}{c}
C=H_2 \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
-\text{OH} \\
C=H_2 \\
\diagdown\!\!\text{OH}
\end{array}
$$
Glycerin.

$$
\begin{array}{c}
C=H_2 \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
-\text{OH} \\
C-\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Glyceric Acid.

$$
\begin{array}{c}
C=\text{O} \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
\diagdown\!\!\text{OH} \\
C-\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Tartronic Acid.

$$
\begin{array}{c}
C\equiv H_3 \\
C=H_2 \\
C=H_2 \\
C\equiv H_2
\end{array}
$$
Butane.

$$
\begin{array}{c}
C\diagup\!\!H_2 \\
\diagdown\!\!\text{OH} \\
C\ H_2 \\
C=H_2 \\
C\equiv H_3
\end{array}
$$
Butyl-alcohol.

$$
\begin{array}{c}
C=\text{O} \\
\text{OH} \\
C\ H_2 \\
C=H_2 \\
C\equiv H_3
\end{array}
$$
Butyric Acid.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
C\ H_2 \\
C=H_2 \\
C\diagup\!\!H_2 \\
\diagdown\!\!\text{OH}
\end{array}
$$
Oxybutyric Acid.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
C=H_2 \\
C=H_2 \\
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Succinic Acid.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
C\diagup\!\!\text{H} \\
\diagdown\!\!\text{OH} \\
C=H_2 \\
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Malic Acid

$$
\begin{array}{c}
C\diagup\!\!\text{H} \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
\diagdown\!\!\text{OH} \\
C\diagup\!\!H_2 \\
\diagdown\!\!\text{OH}
\end{array}
$$
Erythrite.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
\diagdown\!\!\text{OH} \\
C-\text{H} \\
\diagdown\!\!\text{OH} \\
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH}
\end{array}
$$
Tartaric Acids.

$$
\begin{array}{c}
C\equiv H_3 \\
C=H_2 \\
C=H_2 \\
C\equiv H_3
\end{array}
$$
Pentane.

$$
\begin{array}{c}
C\diagup\!\!H_2 \\
\diagdown\!\!\text{OH} \\
C\ H_2 \\
C\equiv H_2 \\
C\equiv H_3
\end{array}
$$
Amyl-alcohol.

$$
\begin{array}{c}
C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
C=H_2 \\
C=H_2 \\
C\equiv H_3
\end{array}
$$
Valerianic Acid.

$$
\begin{array}{c}
C\equiv H_3 \\
C=H_2 \\
C=H_2 \\
C=H_2 \\
C=H_2 \\
C\equiv H_3
\end{array}
$$
Hexane.

$$
\begin{array}{c}
H_2C-\text{OH} \\
H-C-\text{OH} \\
H-C-\text{OH} \\
H-C-\text{OH} \\
H-C-\text{OH} \\
H_2C-\text{OH}
\end{array}
$$
Mannite.

$$
\begin{array}{c}
O=COH \\
H-COH \\
H-COH \\
H-COH \\
H-COH \\
H_2COH
\end{array}
$$
Mannitic Acid.

$$
\begin{array}{c}
O=COH \\
H-COH \\
H-COH \\
H-COH \\
H-COH \\
O=COH
\end{array}
$$
Saccharic Acid.

$$
\begin{array}{c}
O=C-\text{OH} \\
H-CO-H \\
H-C-C\diagup\!\!\text{O} \\
\diagdown\!\!\text{OH} \\
H-C-H \\
O=COH
\end{array}
$$
Citric Acid.

THE PHENOLS.

Compounds derived from the Aromatic or Benzene Hydrocarbons.—It has been thought best to study the derivatives of the benzene hydrocarbons by themselves, because of certain peculiarities of these compounds, and to avoid making the study of the others too complicated. We have already studied the principal hydrocarbons of this series which interest the physician and pharmacist. The H atoms in benzene may be replaced by halogens, hydroxyl, sulphur, or other hydrocarbon radicals. In fact, the higher members of the series are all derived by substitutions for H in the original benzene nucleus. By the substitution of radicals for H in the principal chain, or in the lateral chain, we may form two series of isomeric compounds, few of which are of sufficient interest to claim special study. By the substitution of hydroxyl for H, in benzene, we have what is termed a phenol. By the substitution of two hydroxyls for two atoms of H in benzene, we have the diatomic phenols. By the substitution of three hydroxyls, we have the triatomic phenols. It will be seen that in the higher homologues of benzene, in toluene for example, $C_6H_5CH_3$, where there is a side-chain, it is possible to substitute the hydroxyl for one of the H atoms of the benzene nucleus, or for one on the side-chain. In the first instance we have a phenol; in the second we have an alcohol. That is, the first can not be oxidized to produce an acid, because the carboxyl group COOH can not be produced. In the second we can form COOH by oxidation, and it is therefore a true alcohol. The phenols, therefore, are isomeric with, but have different properties from the alcohols. The phenols differ from the alcohols, in not furnishing corresponding aldehydes and acids on oxidation; in not dividing into water and hydrocarbons under the influence of dehydrating agents, as all alcohols should; and in not reacting with acids to form ethers. The phenols form more stable compounds with metallic elements than the true alcohols. The phenols exhibit acid properties, while the alcohols do not.

The following graphic formulæ will assist the student in comprehending the different derivatives of benzene and toluene:

Benzene.   Toluene, or Methyl-benzene.   Monochlor-benzene.   Benzyl-chloride.

OH	CH$_2$OH	OH OH	OH CH$_3$
Phenol.	Benzyl-alcohol.	Diatomic Phenol.	Orthocresol.

COH	CO.OH	OH CO.OH	NH$_2$
Benzoic Aldehyde.	Benzoic Acid.	Salicylic Acid.	Benzamin.

NH$_2$
CH$_3$

Toluidin, or Toluyl-amin.
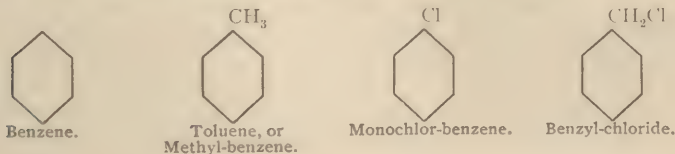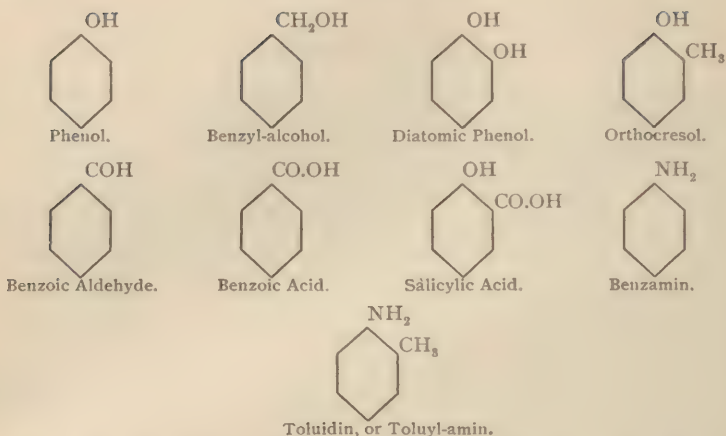
The phenols exhibit acid properties, while in structure they are allied to the alcohols.

Phenol, phenic acid, carbolic acid, acidum carbolicum

$$C.—O—H$$
$$HC_6 \quad _2CH$$
$$HC_5 \quad _3CH$$
$$C$$
$$H$$

(U. S. P., Br.),   , is met with in the products of
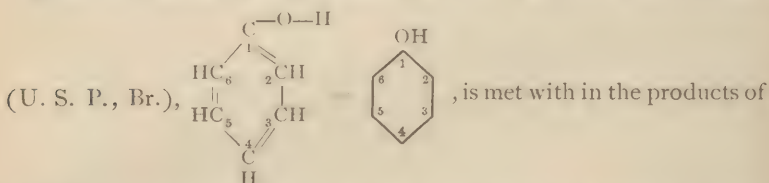
the destructive distillation of coal and wood, and is found in small quantities in human urine and in castoreum. In the arts it is prepared from that portion of coal-tar distilling between 150° C. (302° F.) and 190° C. (374° F.). This is agitated with a concentrated solution of caustic soda, when a crystalline carbolate of sodium is formed, while the neutral oils are left unacted upon. After the latter have been separated, the carbolate is decomposed by hydrochloric acid, and the impure carbolic acid thus obtained again treated with sodium hyroxide. On exposing this solution to the air, the greater portion of the impurities becomes oxidized, and separates as a tarry mass. This mass is roasted, the carbolate dissolved out, and the clear solution of sodium phenate (or carbolate) is again decomposed by hydrochloric acid, and the resulting carbolic acid separated and submitted to distillation. From the portion passing over below 190° C. (374° F.) phenol separates out as colorless needles on cooling, which melt at 42° C.

(108° F.) and boil at 184° C. (364° F.). In recent years a **synthetic carbolic acid,** prepared from benzene, has come into the market.

Pure phenol is a crystalline solid, having a characteristic odor and pungent, caustic taste, producing a white eschar with animal tissues. The crystals are liquefied by the addition of about 8 per cent. of water. This liquid is made turbid by the addition of more water. It is soluble in 20 parts of water at the ordinary temperature, but is miscible in all proportions in boiling water. The addition of glycerin increases its solubility. It is readily soluble in alcohol, ether, benzene, carbon disulphide, glycerin, and fixed and volatile oils. Carbolic acid coagulates albumin, and its aqueous solution gives a permanent violet-blue color with ferric chloride, while that produced by creosote is first green and then brown. It forms with bromine-water a white precipitate of tribromphenol. When quite pure, carbolic acid is permanent in the air; but the commercial acid frequently changes to a pink or red color. Ammonia and chlorinated soda solution produce a blue color with carbolic acid. Carbolic acid is very much used as an antiseptic in medicine, and in the arts. Some of the carbolates have also been used for the same purposes. Carbolic acid is very poisonous when taken into the body, and cases of fatal poisoning by it are not uncommon. Dangerous symptoms have been produced by six or seven drops, and fatal poisoning has occurred from its use as a surgical dressing. The urine is dark-colored and smoky in such cases, and its appearance should be watched while using the acid, either internally or locally. The best **antidote** to administer in cases of poisoning is a solution of sodium sulphate in water, with which carbolic acid forms sodium sulphocarbolate, which is harmless. This may be followed by alcoholic stimulants and mucilaginous drinks. The stomach-tube may also be used to empty the stomach.

Phenates.—When phenol is heated with KOH or NaOH, the following reaction takes place:

$$C_6H_5OH + KOH = C_6H_5OK + H_2O.$$

Phenol.   Potassium Phenate.
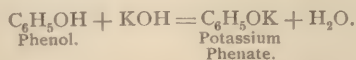
Phenol here behaves like an acid, and thus gives rise to the name phenic acid or carbolic acid. Certain other metals and the alkaloids may be employed to replace the alcoholic H of phenol, to give phenates. Mercuric phenate, quinine phenate, and even other salts of this class have been employed in medicine.

Chlorphenols and Bromphenols.—When chlorine is passed into phenol, ortho- and para-chlorphenols are formed. The corre-

sponding Br and I substitution products are obtained by the action of these elements on phenol.

Monochlorphenol, C_6H_4ClOH, has been employed as a remedy for inhalations in phthisis and other lung troubles. It is a volatile liquid, having an odor somewhat resembling phenol.

Bromol, or **tribromphenol,** $C_6H_2Br_3OH$, also called tribromophenol, is prepared by the action of Br upon an aqueous solution of phenol. It occurs as a white, crystalline powder of an astringent, sweetish taste, and an odor resembling that of bromine. It melts at 95° C. (203° F.). It is insoluble in water, but soluble in alcohol, ether, chloroform, glycerin, and the fatty and ethereal oils. It has been recommended as a local remedy in diphtheria and as an intestinal antiseptic.

Trinitrophenol, picric acid, carbazotic acid, $C_6H_2(NO_2)_3$-OH.—The phenols are acted upon by strong nitric acid, forming mononitro-, dinitro-, and trinitro-phenols. The first two of these are of little importance to the physician, but the third is employed in the arts as a yellow dye for silk and wool, and is frequently employed as a test for albumin in urine, and as a precipitant of the alkaloids. Two trinitrophenols are known, in one of which the NO_2 groups are attached to carbon atoms 1, 2, and 4, and in the other attached to 2, 4, and 6. The latter compound is ordinary picric acid. It is prepared by the action of strong nitric acid upon phenol, salicin, indigo, silk, wool, and many other organic substances containing the benzene nucleus. It occurs in yellow, crystalline plates. It is nearly odorless, and has an intensely bitter taste and an acid reaction. It is sparingly soluble in water, very soluble in alcohol, ether, and benzene. When quickly heated, it detonates. It forms salts with the metals, which are explosive. When taken internally in considerable doses it acts as a poison.

Tests.—1. Its taste is so bitter that this, together with its bright lemon-yellow color, serves as a delicate test.

2. Its solutions give a green, crystalline precipitate with an ammoniacal solution of $CuSO_4$.

3. Glucose heated with an alkaline solution of the acid gives a reddish-brown colored solution.

4. It gives an intense red color when warmed with an alkaline solution of KCN.

PHENOLS DERIVED FROM TOLUENE, OR THE CRESOLS.

Cresylic Acid, or Cresol.—$C_6H_4 \begin{cases} CH_3 \\ OH \end{cases}$. There are three possible compounds having this formula,—the ortho-, meta-, and para-cresols, —depending upon the relative positions of the OH and CH_3 groups in the molecule, as shown by the following graphic formulæ :

Orthocresol.   Metacresol.   Paracresol.
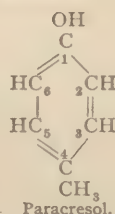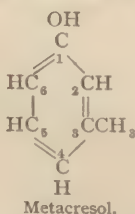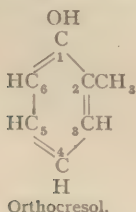
Two of these, at least, are found in coal-tar, together with phenol, and are obtained from it by fractional distillation. The impure varieties of commercial coal-tar creosote, or carbolic acid, contain in addition cresylic acid, or cresol. Cresol may be prepared by dissolving toluidin in sulphuric acid, adding potassium nitrite, and distilling with steam.

$$C_6H_4CH_3NH_2 + KNO_2 + H_2SO_4 = C_6H_4CH_3OH + H_2O + N_2 + KHSO_4.$$
$$\text{Toluidin.} \qquad\qquad\qquad\qquad \text{Cresol.}$$
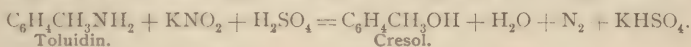
By the same method of preparation the three isomeric cresols are prepared from the three corresponding isomeric toluidins.

The position of the substituted groups is often indicated by figures showing the carbon atoms to which they are attached ; as follows :

Orthocresol ($1 : 2$) is a crystalline solid, fusing at $31°$ C. ($87.8°$ F.) and boiling at $185°$ C. ($365°$ F.).

Metacresol ($1 : 3$) is a liquid, boiling at $195°$ C. ($383°$ F.).

Paracresol ($1 : 4$) is a solid, fusing at $36°$ C. ($96.8°$ F.) and boiling at $198°$ C. ($388°$ F.). Paracresol occurs in the urine as potassium cresol-sulphate, and is a product of the putrefaction of albumin in the intestinal canal.

Tricresol, a commercial disinfectant, is a mixture of the three cresols in their natural proportions, carefully freed from all impurities. It is a colorless, oily liquid of sp. gr. 1.045, and soluble in 40 parts of water, giving a clear neutral solution. Its disinfectant power is three times that of carbolic acid.

Paracresol benzoate, $C_6H_5COO.C_6H_4.CH_3$, is a crystalline compound, said to be a powerful disinfectant.

Beech-wood creosote,* **creosotum** (U. S. P., Br.), is a mixture of phenols consisting chiefly of guaiacol and cresols obtained during the distillation of wood-tar, preferably that of the beech. It contains, in addition to the above, a small quantity of phlorol. It is an almost colorless, yellowish or pinkish, highly refractive, oily liquid, having a penetrating, smoky odor, and a burning, caustic taste. Its sp. gr. is 1.070 or higher. It is soluble in about 150 parts of water, but it does not form a perfectly clear solution. It is soluble in all proportions in alcohol, ether, chloroform, benzene, carbon disulphide, acetic acid, fixed and volatile oils. It begins to boil at about 205° C. (401° F.), and most of it distils between 205° and 215° C. (401° and 419° F.). When cooled to —20° C. (—4° F.) it does not solidify like carbolic acid, but becomes gelatinous. It is inflammable. Its solution gives a reddish-brown precipitate with bromine water, which distinguishes it from phenol.

Creosote is employed in medicine, both internally and externally and by inhalations. It is also employed as an antiseptic.

To distinguish creosote from phenol, which is often substituted for creosote, the following tests may be applied. Phenol gives with Fe_2Cl_6 a purple-colored solution, while creosote gives a violet, which rapidly changes to green and finally to brown, with the formation of a brown precipitate. Phenol is soluble in glycerin, while creosote is not. Phenol precipitates collodion from its solution, while creosote does not.

Creosote carbonate is a mixture of guaiacol carbonate with a trace of cresol. It is prepared by saturating partially purified guaiacol with sodium hydroxide, and treating this compound with carbonyl chloride, $COCl_2$. It is an amber-colored fluid, honey-like in consistency, with a faint odor and taste of creosote. It is used in medicine as a substitute for creosote, it being free from its disagreeable taste.

The cresols possess wonderful antiseptic properties, and are less poisonous to the animal organism than phenol. A serious hindrance to their employment as germicides is their insolubility. Cresols have recently been introduced as disinfectants under special names, as **creolin, lysol, solveol,** and **solutol.** These substances are derivatives from cresols. **Creolin** is a dark-brown, alkaline liquid. It is free from caustic or irritating properties, and may be administered internally. It forms with water a more or less turbid or milky mixture or emulsion. It mixes with chloroform, ether, and dilute alcohol in all proportions. For external application it is used in the form of an ointment, or as a 1 to 2 per cent. aqueous solution.

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* Also spelled "creasote."

Lysol is a preparation resembling creolin in its properties, and is made by dissolving the fraction of coal-tar oil, which boils between 190° and 200° C. in fat, and afterward saponifying with alkalies, with the addition of alcohol. It is a brown, oily-looking, clear liquid, with an aromatic, creosote-like odor. It is said to contain 50 per cent. of cresols. It is miscible with water, forming a clear, saponaceous, frothing liquid; also with alcohol, benzene, chloroform, and glycerin. It is a good disinfectant, five times more active than phenol, and much less poisonous. It is non-caustic.

Solveol is a solution of sodium cresol in excess of cresol. **Solutol** is a solution similar to solveol. It is said to contain 60 per cent. of cresylic acid—one-fourth in the free state and three-fourths combined with sodium. **Cresol iodide** has also been introduced into medicine in the form of a light yellow powder of not very pleasant odor. It is insoluble in water, but soluble in the oils, alcohol, ether, and chloroform.

Cresotic Acids, Oxytoluic Acids.—$C_6H_3CH_3OHCOOH$. There are three of these, corresponding to the ortho-, meta-, and para-cresols. They are prepared by the action of sodium hydroxide and carbon dioxide upon the cresols, according to Kolbe's method of preparing salicylic acid from phenol. They may also be prepared by melting the homologues of phenol with excess of potassium hydroxide. The cresotic acids all crystallize in long, white, prismatic needles, which can be volatilized in a current of steam. They are soluble with difficulty in cold, but more so in hot water; readily soluble in alcohol, ether, and chloroform. In solution their reactions are similar to salicylic acid. Several salts of cresotic acid have been suggested as medicinal remedies. **Sodium cresotate** and **sodium para-cresotate**, $C_6H_3 \begin{cases} CH_3 \\ OH \\ COONa \end{cases}$, have been used. The latter salt is a fine, crystalline powder with a bitter taste, soluble in 25 parts of water. It has been used in rheumatism, in doses of from 8 to 45 grains.

Dimethyl-phenols, Xenols, Xylenols.—$C_6H_3, \begin{cases} CH_3 \\ CH_3 \\ OH \end{cases}$ There are six possible dimethyl-phenols, four of which have been obtained. We may also have three possible ethyl-phenols, $C_6H_4 \begin{cases} C_2H_5 \\ OH. \end{cases}$

Thymol, propyl-metacresol, $C_6H_3 \begin{cases} CH_3 \\ C_3H_7 \\ OH \end{cases}$ has already been described among the camphors.

Carvacrol, or **propyl-orthocresol,** $C_6H_3 \begin{cases} CH_3 \\ C_3H_7, \\ OH \end{cases}$ exists in the

essential oil of origanum. It is an isomer of thymol. It is a thick, oily liquid, which does not solidify even at $-25°$ C. ($-13°$ F.). It boils at $233°$ C. ($451.4°$ F.). It is very soluble in chloroform, ether, and olive oil, but insoluble in water. Its iodide is a yellow-brown powder, sometimes employed in medicine. It is obtained by the action of iodine upon camphor. It is employed externally as a substitute for iodoform.

Eugenol, or **eugenic acid,** $C_6H_3 \begin{cases} OCH_3 \\ C_3H_5, \\ OH \end{cases}$ is a body closely re-

sembling carvacrol, obtained from the oil of cloves, cinnamon, bay, pimento, or sassafras, by oxidation. Eugenol occurs as an aromatic liquid, boiling at $235°$ C. ($455°$ F.), slightly soluble in water, freely so in alcohol. It is employed as an antiseptic, and is considered superior to phenol. It has also been used internally as a febrifuge. Several compounds of eugenol have also been employed, **benzoyl-eugenol, cinnamyl-eugenol, iodo-eugenol,** and **eugenol-acetamid** being the principal ones.

A **di-iodo thymol,** $\begin{matrix} C_3H_7 \\ CH_3 \end{matrix} \Big\} C_6H_2(IO)-(IO)C_6H_2 \begin{cases} C_3H_7 \\ CH_3 \end{cases}$, formed

by the action of a solution of I in KI upon an alkaline solution of thymol, has been proposed as a substitute for iodoform, under the name of **annidalin.** It occurs as a reddish-brown, odorless powder, which is decomposed under the action of heat and light, with evolution of iodine. This substance is now more generally known as **aristol.** It is insoluble in water and glycerin, slightly soluble in alcohol, and readily so in ether and collodion. It mixes readily with the oils or with vaseline when rubbed with them. When heated in a glass tube, iodine vapors are given off.

Naphthophenols, or **Naphthols.**—$C_{10}H_7OH$. There are two compounds of this formula, one known as alpha- and the other as beta-phenol. The graphic formulæ are:

α-Naphthol. and α-Naphthol. β-Naphthol.
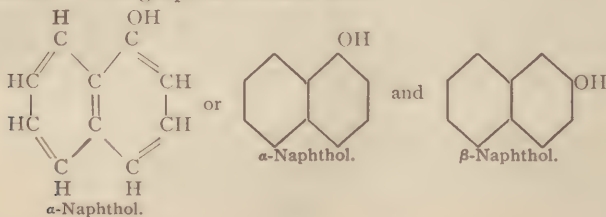
The one generally used in surgery is **beta-naphthol**. **Alpha-naphthol** crystallizes in colorless, shining prisms, fusing at 94° C. (201.2° F.) and boiling at 280° C. (536° F.). It is insoluble in water, but soluble in alcohol, ether, and benzene. Beta-naphthol is prepared on a large scale by fusing naphthalene-sulphonate of sodium, $C_{10}H_7SO_3Na$, with sodium hydroxide. Beta-naphthol is a solid, crystallizing in brilliant white plates, melting at 122° C. (251.6° F.) and distilling at 286° C. (546.8° F.), and possesses a sp. gr. of 1.217. It is very slightly soluble in warm water, very soluble in ether, alcohol, chloroform, benzene, olive oil, and vaseline. Beta-naphthol has been used as a local antiseptic. **Alpha-naphthol** forms a dinitro- derivative, $C_{10}H_5(NO_2)_2OH$, which is used in dyeing. The sodium and calcium salts of this compound are used, and are known as Martin's yellow or naphthalene yellow. These have recently been largely replaced by the potassium sulphonate known as naphthol yellow,

$$C_{10}H_4(NO_2)_2 \begin{cases} SO_3K. \\ OK. \end{cases}$$

Hydronaphthol, occasionally employed as a surgical dressing, is a dihydronaphthalene :
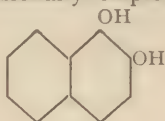
DIATOMIC PHENOLS.

These compounds are derived from benzene and its homologues by replacing two atoms of hydrogen by hydroxyl. They may be prepared by fusing phenolsulphonic acid with KOH.

$$C_6H_4OH_2SO_3 + KOH = HKSO_4 + C_6H_4(OH)_2.$$
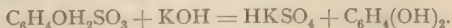
There are three such compounds possible, all of which, in the case of benzene, are well known. Their graphic formulæ, as well as the cause of the isomerism, are shown by the following :
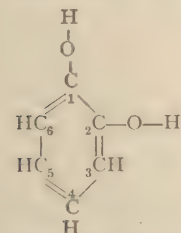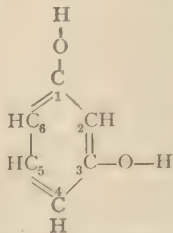
Ortho-dihydro-phenol.   Meta-dihydro-phenol.   Para-dihydro-phenol.

Or,

$C_6H_4(OH)_2(1:2)$ $C_6H_4(OH)_2(1:3)$ $C_6H_4(OH)_2(1:4)$
Pyrocatechin.   Resorcin.   Hydroquinon.
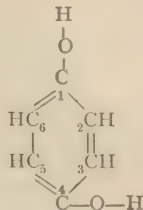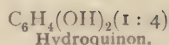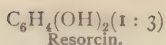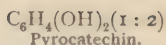
It will be observed that in the first formula the hydroxyls occupy positions on two adjoining carbon atoms, or on 1 and 2. In the second the positions are 1 and 3, and in the third they are 1 and 4. These three include all the possible relative positions of two hydroxyl groups in this molecule. The properties change with the relative positions of the two hydroxyl groups.

Ortho-dihydro-phenol, or **pyrocatechin,** $C_6H_4 \begin{cases} OH\ (1) \\ OH\ (2) \end{cases}$, is an isomeride of hydroquinon and resorcin that has found use as a remedial agent. It forms flat crystals or plates, readily soluble in water, alcohol, and ether. It is prepared by distilling extract of catechu, kino, and other extracts containing tannin. It is found in crude pyroligneous acid distilled from wood. It has weak acid properties.

Solutions of pyrocatechin reduce silver salts in the cold, and Fehling's solution on warming. If made alkaline, they absorb oxygen from the air and turn green.

Meta-dihydro-phenol resorcin, resorcinol, $C_6H_4 \begin{cases} OH(1) \\ OH(3) \end{cases}$, an isomeride of hydroquinon, has come into prominence in the treatment of certain maladies. It forms colorless crystals, melting at about 100° C. (212° F.), and boiling at 276° C. (528.8° F.). It is very soluble in water, alcohol, and ether, and possesses a sweetish, harsh taste. It is prepared by fusing certain gum-resins (galbanum, extract of sapin-wood; or, by distilling Brazil-wood) with caustic potash. It is a strong antifermentative. It is now prepared synthetically from benzene, but the process is complicated.

When a small quantity is warmed with twice its weight of tartaric acid and 10 drops of H_2SO_4, it gives a dark carmine-red liquid. A solution of 5 parts of resorcin and 3 parts of white sugar in 100 parts of alcohol forms a very delicate test for free HCl, when warmed in a dish with the suspected fluid. It is used to detect free HCl in the gastric juice. It gives with HCl a purple-red color. The **physiological action** of resorcin is similar to that of phenol, but it is not poisonous. It is given internally as an antiseptic and antipyretic, in doses of 2 grains, and in some cases as high as 15 grains (1 gm.).

Fluorescein, or **resorcin-phthalein,** $C_{20}H_{12}O_5 \cdot H_2O$, is also used in medicine, and occurs as dark-brown crystals, which, by heating resorcinol with phthalic anhydride, dissolving in H_2SO_4, and adding ammonia, produces a beautiful red solution with a green fluorescence. This reaction is used as a test for resorcinol.

Para-dihydro-phenol, or **hydroquinon,** $C_6H_4\begin{Bmatrix} OH(1) \\ OH(4) \end{Bmatrix}$, is most easily prepared by passing SO_2 through a warm saturated solution of quinon, $C_6H_4O_2$, when hydroquinon separates in six-sided prisms, fusing at 169° C., and subliming on further heating. It is moderately soluble in water and easily soluble in alcohol and ether. It has been recommended as an antipyretic, antifermentative, and antidiarrheal remedy.

It is claimed that it is harmless, even in large doses. It is given in 5- to 8-grain doses. It is used in photography as a developer, owing to its reducing properties.

Quinon, $C_6H_4 = O_2$, is a type of a number of compounds obtained by the oxidation of a number of parabenzene derivatives. It is a yellow, crystalline powder, subliming slowly at ordinary temperatures. Nascent hydrogen or reducing agents convert it into hydroquinon.

Orcin, orcinol, dihydroxytoluene, $C_6H_3CH_3(OH)_2$, is prepared from certain lichens which furnish **litmus, cudbear,** and **archil.** The lichens are boiled with lime and water, the lime precipitated with CO_2, and the orcin extracted with ether. Orcin crystallizes in prisms, has a sweet taste, and is soluble in water, alcohol, and ether. Orcin forms with ammonia a purple solution, from which acetic acid precipitates a red coloring matter, **orcein,** the chief coloring matter of litmus, and the other dyes made from lichens, by mixing them with lime and urine, and exposing them to the air.

$$C_7H_8O_2 + NH_3 + O_3 = 2H_2O + C_7H_7NO_3$$
$$\text{Orcin.} \qquad\qquad\qquad\qquad\qquad \text{Orcein.}$$
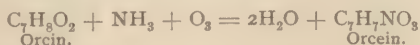
Guaiacol, or **methyl-pyrocatechin,** $C_6H_4\begin{Bmatrix} OCH_3 \\ OH \end{Bmatrix}$, is a constituent of creosote, of which it constitutes about 60 to 90 per cent.

It is prepared by the fractional distillation of beech-wood creosote, collecting that coming over between 200° and 205° C.

It is a liquid having a pleasant odor, and boiling at a little above 203° C. (397.4° F.). Its sp. gr. is 1.133 at 15° C. (59° F.). It is not very soluble in water, requiring 85 parts of water to dissolve 1 part of it.

It is used as a remedy in tuberculosis in place of creosote. It is best given in capsules.

Guaiacol iodide, guaiacol carbonate, guaiacol carbonic acid, cinnamyl guaiacol, and **guaiacol salicylate** have been prepared, and proposed for the same uses as guaiacol.

Of these compounds the **carbonate** is most used.   It is prepared by the action of carbonyl chloride on a solution of guaiacol sodium.

$$2C_6H_4CH_3O_2Na + COCl_2 = \begin{matrix} C_6H_4CH_3O \\ C_6H_4CH_3O \end{matrix}{>}CO_3 + 2NaCl.$$

Guaiacol Sodium.   Guaiacol Carbonate.
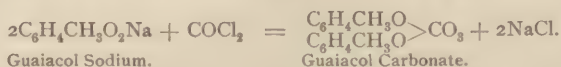
The separating crystals are collected and recrystallized from alcohol. It is a white, crystalline powder, nearly free from odor and taste, insol-uble in water, and sparingly soluble in alcohol, glycerin, and oils.   It is decomposed by alkalies, into carbonic acid and guaiacol.   It is used for the same diseases as guaiacol and creosote.

Benzoyl guaiacol, benzosol, $C_6H_4\begin{cases} OCH_3 \\ OCOC_6H_5 \end{cases}$, is a crystalline compound of guaiacol in which the H of the OH group has been replaced by benzoyl.   It is prepared by first forming the potassium salt of guaiacol, and warming this with benzoyl chloride, or, by the reaction between guaiacol and benzoic anhydride.   Benzosol is a colorless, tasteless, nearly odorless crystalline powder.   It is insoluble in water, soluble in hot alcohol, in ether and chloroform.   It con-tains 54 per cent. of guaiacol.   It should not melt below 44° C. (111.2° F.).

Benzosol is used for the same purposes as guaiacol, and it is de-composed by the alkalies in the same manner as salol.   It is given internally in doses of 4 to 12 grains.

Guaiacol and its derivatives are not easily oxidized in the body, and are usually partially excreted in the urine, and may be detected in that fluid one-half hour after taking a single dose.   It may be detected by distilling the urine with dilute H_2SO_4, and adding a drop or two of ferric chloride solution to the distillate, when, if guaiacol be present, it will give a reddish-brown color.

TRIATOMIC PHENOLS.

There are three isomeric trioxybenzenes : phloroglucin, pyrogallol, and oxyhydroquinon.

Phloroglucin, phloroglucol, $C_6H_3(OH)_3$ (1 : 3 : 5), is obtained by the fusion of KOH or NaOH with various resins or resorcin, or by the action of alkalies upon phloretin.   It occurs as large prisms, which dissolve in water, alcohol, and ether, and possesses a very sweet taste.   Its solutions give a dark violet color with Fe_2Cl_6.   A solution of 2 parts of phloroglucin and 1 part of vanillin in 30 of absolute alcohol is used as a very delicate test for free HCl in

gastric juice. It will detect 1 part of HCl in 20,000 parts of water (Günzburg).

Pyrogallin, Pyrogallol (U. S. P.), **or Pyrogallic Acid.—**

$C_6H_3 \begin{cases} O-H \ (1) \\ O-H \ (2) \\ O-H \ (3) \end{cases}$ This is a trihydrobenzene, and is prepared by

heating gallic acid, $C_6H_2(OH)_3CO_2H$, to 300° C. (572° F.). It crystallizes in white, shining needles, and gives a dark blue color with ferrous, and red with ferric salts. An alkaline solution, when exposed to the air, rapidly absorbs oxygen and assumes a dark color. Silver and gold salts are reduced, in the light, to the metallic state by it; hence it is used as a developer in photography. It has been used in the treatment of skin diseases.

Oxyhydroquinon, $C_6H_3(OH)_3$ (1 : 2 : 4), is unimportant.

There are no tetratomic phenols used in medicine. Pentatomic and hexatomic phenols have been prepared.

Aromatic Alcohols.

The **aromatic alcohols** differ from the phenols in constitution. They all contain the group of atoms CH_2OH, and by the oxidation of this group it becomes COH, then $COOH$, with the formation of an aldehyde and an acid, thus:

$$C_6H_5CH_2OH + O = C_6H_5COH + O = C_6H_5COOH + H_2O.$$
$$\text{Benzylic Alcohol.} \qquad \text{Benzoic Aldehyde.} \quad \text{Benzoic Acid.}$$

Benzylic alcohol is formed by distilling benzoic aldehyde with KOH.

$$2C_6H_5CHO + KOH = C_6H_5CH_2OH + C_6H_5COOK.$$
$$\text{Benzaldehyde.} \qquad \text{Benzyl-alcohol.} \quad \text{Pot. Benzoate.}$$

Its benzoic and cinnamic ethers are found in balsams of Peru and tolu. It is a colorless liquid, of theoretical interest only.

Salicylic alcohol, saligenin, $C_6H_4 \begin{cases} OH \\ CH_2OH \end{cases}$, is one of the constituents of the natural glucoside, **salicin.** It may be separated from salicin by decomposition with dilute mineral acids, but it is more easily prepared by the action of formaldehyde upon phenol.

$$C_6H_5OH + HCHO = C_6H_4 \begin{cases} OH. \\ CH_2OH. \end{cases}$$
$$\text{Phenol.} \quad \text{Formaldehyde.} \qquad \text{Saligenin.}$$
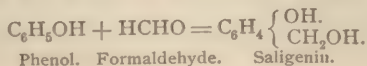
It has been recommended as a substitute for salicylic acid.

Saligenin crystallizes in colorless leaflets, having a slightly bitter

taste. It is fairly soluble in cold and easily soluble in hot water and in alcohol.

Cinnamyl-alcohol, styrone, $C_6H_5.CHCHCH_2OH$, occurs as a cinnamic ester, known as styracin, in storax (Styrax officinalis, U. S. P.).

It forms shining, needle-like crystals, having a hyacinth-like odor, and is sparingly soluble in water. On oxidation it gives at first cinnamic acid, $C_6H_5CHCHCOOH$, and then benzoic acid, C_6H_5COOH.

AROMATIC ALDEHYDES.

Benzaldehyde, oleum amygdalæ amaræ (U. S. P., Br.), C_6H_5-COH, is a constituent of bitter almond oil, and is a product of the decomposition of **amygdalin,** along with hydrocyanic acid, glucose, and benzoic acid, under the action of the emulsin ferment. It is now prepared from toluene, by treatment with chlorine, forming benzoyl dichloride, $C_6H_5CHCl_2$, and heating this with lime, under pressure.

$$C_6H_5CHCl_2 + C(OH)_2 = CaCl_2 + C_6H_5CHO + H_2O.$$
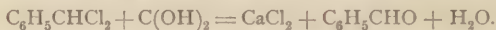
It is prepared from the oil, by forming a crystalline solid with sodium bisulphite, separating the crystals, and, after dissolving them in water, decomposing with a strong solution of Na_2CO_3. It is a colorless, oily liquid with the odor and taste of bitter almonds. Specific gravity, 1.043; boiling point, 179° C. (354.2° F.). Oxidizing agents give benzoic acid, and nascent hydrogen gives benzylic alcohol. When pure it is not poisonous, but the commercial article is seldom free from hydrocyanic acid.

Salicylic aldehyde, salicylal, $C_6H_4 \begin{cases} COH \\ OH \end{cases}$, or oil of spiræ (meadow-sweet), is obtained by oxidizing **salicin** with $K_2Cr_2O_7$ and H_2SO_4 and distilling off the aldehyde. It may be prepared synthetically by the action of chloroform and KOH on phenol. Salicylic aldehyde is a colorless, fragrant liquid, sp. gr. 1.17, and boiling at 196° C. (384.8° F.). It is sparingly soluble in water, but freely in alcohol. It gives an intense violet color with Fe_2Cl_6.

Cinnamic aldehyde, C_6H_5CH CHCOH, is the chief constituent of the oils of cinnamon and cassia. It may be isolated by means of its compound with sodium bisulphite. It has been prepared synthetically. It is a colorless, aromatic oil, boiling at 247° C. (476.6° F.) and oxidizing to cinnamic acid (C_6H_5CH=$CHCOOH$) on exposure to the air.

Cuminic aldehyde, $C_9H_{11}COH$, occurs in the aromatic oils of cummin, caraway, and water-hemlock.

Anisic aldehyde, $C_6H_4OCH_3COH$, is obtained as a fragrant oil, by oxidizing the oil of fennel and the oil of anise with HNO_3.

Vanillic aldehyde, or **vanillin,** $C_7H_7O_2COH$, is extracted from the pods of the vanilla bean—*Vanilla planifolia.* It is now made synthetically from coniferin, a glucoside found in the bark of trees of the *conifera* family.

AROMATIC KETONS.

The ketons, corresponding to the secondary aromatic alcohols, may be formed by the same process and have the same class properties as those of the methane series.

Phenyl-methyl-keton, acetophenon, hypnon, $C_6H_5CO.CH_3$, is prepared by distilling a mixture of molecular proportions of calcium acetate and calcium benzoate: $Ca(C_6H_5COO)_2 + Ca(C_2H_3O_2)_2 = 2CaCO_3 + 2C_6H_5COCH_3$. It is a colorless, oily liquid, with a peculiar odor and pungent taste. It crystallizes at $14°$ C. $(57.2°$ F.$)$, and melts again at $20.5°$ C. $(69°$ F.$)$. It is slightly soluble in water, but readily miscible with alcohol. It has been used as a hypnotic. Dose, 1 to 3 minims.

Gallacetophenon, $C_2H_3O.C_6H_2(OH)_3$, is a derivative of pyrogallol, containing the radical of acetic acid. It is prepared by the action of pyrogallol upon glacial acetic acid in the presence of zinc chloride. It is a pale-yellow, crystalline powder, readily soluble in hot water and in alcohol and ether. It is soluble in glycerin, but sparingly soluble in cold water.

It has been used as an external remedy in psoriasis.

Phenyl-ethyl-keton, $C_6H_5COC_2H_5$, **phenyl-propyl-keton,** $C_6H_5CO-C_3H_7$, and **diphenyl-keton, benzophenon,** $C_6H_5-CO-C_6H_5$, are also known.

QUINONS.

Quinons are a class of bodies derived from aromatic hydrocarbons by substitution of O_2'' for H_2''. They are therefore oxidation products of the hydrocarbons.

Benzoquinon, or **quinon,** $C_6H_4=O_2$, may be obtained by heating benzene with chromyl chloride, CrO_2Cl_2. The reaction takes place in two stages, as follows:

1. $C_6H_6 + 2CrO_2Cl_2 = 2HCl + C_6H_4(CrO_2Cl_2)_2$.
2. $C_6H_4(CrO_2Cl_2)_2 + H_2O = C_6H_4O_2 + Cr_2O_3 + 2HCl$.

It may also be prepared by oxidizing benzene and many benzene derivatives with potassium dichromate and sulphuric acid. Reducing agents, such as SO_2, convert quinon into hydrochinon, already described. From the ease with which quinon may be converted into meta-hydroquinon, $C_6H_4(OH)_2$ 1:4, it is believed that the dyad group $(O_2)''$ is attached to the positions 1 and 4.

Naphthoquinons.—There are two naphthoquinons—alpha-**naphthoquinon**, $C_{10}H_6=O_2$ 1 : 4, and beta-**naphthoquinon**, $C_{10}H_6=O_2$ 1 : 2. The first is therefore a paraquinon and the second an orthoquinon.

Anthraquinon, $C_6H_4\diagdown\genfrac{}{}{0pt}{}{CO}{CO}\diagup C_6H_4$, is prepared by dissolving anthra-

cene in glacial acetic acid, and oxidizing by adding chromic anhydride to the hot solution. The quinon separates on the addition of water, and is purified by sublimation. Anthraquinon is chiefly used in the manufacture of alizarin.

Alizarin is formed from anthraquinon by the action, first, of fuming sulphuric acid, by which sulphonic acids are produced. These are heated with potassium chlorate, and then with NaOH.

$$C_6H_4 \genfrac{}{}{0pt}{}{CO}{CO} C_6H_4 + H_2SO_4 = C_6H_4(CO)_2C_6H_3HSO_3 + H_2O.$$
$$C_6H_4(CO)_2C_6H_3HSO_3 + NaOH = C_6H_4(CO)_2C_6H_3OH + NaHSO_3.$$
$$C_6H_4(CO)_2C_6H_3OH + O = C_6H_4(CO)_2C_6H_2(OH)_2.$$
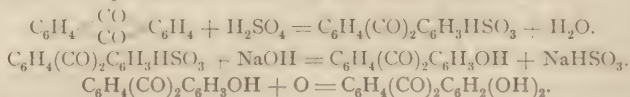
The alizarin formed combines with the excess of NaOH present to form sodium alizarate. This is dissolved in water and the alizarin precipitated with hydrochloric acid. Alizarin is a fine, red, crystalline powder, readily soluble in alcohol. It is a valuable dye-stuff, and has nearly displaced madder in the dyeing industry.

Alizarin monosulphonate of sodium, $C_6H_3NaSO_3(CO)_2C_6H_2$-$(OH)_2$, a yellow dye-stuff, is employed as an indicator in the examination of gastric contents.

By the reduction of alizarin with nascent hydrogen, **anthrarobin** is produced.

$$C_6H_4(CO)_2C_6H_2(OH)_2 + 2H_2 = C_2H_4\diagup\genfrac{}{}{0pt}{}{C(OH)}{CH}\diagdown C_6H_2(OH)_2 + H_2O.$$

Alizarin.   Anthrarobin.
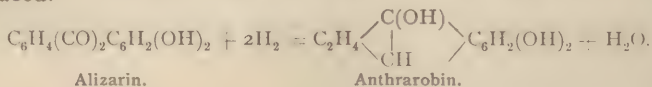
Anthrarobin has been used in medicine as a local application in skin diseases.

AROMATIC ACIDS.

Benzoic Acid, Acidum Benzoicum (U. S. P., Br.).—
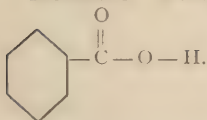
$-\overset{\overset{O}{\|}}{C}-O-H$. This acid occurs in **gum-benzoin** and in the

leaves of the aspen ; it is also found in the urine of herbivorous animals. Benzoic acid was formerly prepared from gum-benzoin by sublimation. The powdered resin was gently heated in an iron pan covered with a perforated paper cover ; over this was placed a paper or felt cone ; the benzoic acid was sublimed and collected on the inner surface of the cone. It was also prepared by boiling the resin with milk of lime, filtering, concentraing the filtrate by evaporation, and precipitating the acid with hydrochloric acid. It is now prepared from toluene by treatment with HNO_3.

$$C_6H_5CH_3 + 2HNO_3 = C_6H_5CO_2H + 2H_2O + 2NO.$$
$$\text{Toluene.} \qquad\qquad \text{Benzoic Acid.}$$

It is also obtained as a side-product in the preparation of benzaldehyde from toluene.

Properties.—**Benzoic acid** occurs in large, thin, glistening plates, or needles ; it melts at 120° C. (248° F.) and boils at 250° C. (482° F.), but sublimes at a lower temperature. It is soluble in hot water and alcohol, but sparingly soluble in cold water. It has a peculiar, aromatic, irritating odor.

The **benzoates** are generally soluble in water.

The benzoates of ammonium, lithium, and sodium are official. The one most used is ammonium benzoate. This salt occurs in colorless, transparent, prismatic crystals, or in white, granular crystals, becoming yellow on long exposure to the air. It has a slight odor of the acid and a saline, afterward bitter, taste ; soluble in 5 parts of water.

The sodium salt is soluble in 1.8 parts of water, has a sweet, astringent taste, is free from bitterness, and has a neutral reaction. The acid and its salts have an antifermentative and antiseptic action. The benzoates may be taken internally without harm. They are eliminated by the urine, partly unchanged and partly as hippuric acid.

Solutions of benzoates give a flesh-colored or reddish precipitate with ferric chloride.

Salicylic or Oxybenzoic Acid, Acidum Salicylicum

(U. S. P., Br.).—$C_6H_4(OH)COOH = C_6H_4(OH)CO_2H.$
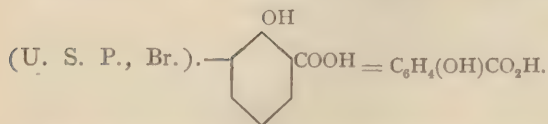
This acid occurs in the flowers of several species of *spiræa*, and its methyl-ether, $C_6H_4 \begin{cases} OH \\ COOCH_3 \end{cases}$, forms a large part of oil of wintergreen, from which it was formerly prepared. It is now prepared on a large scale by passing CO_2 into a heated retort containing sodium carbolate.

$$C_6H_5ONa + CO_2 = C_6H_4(OH)CO.ONa.$$
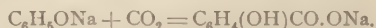
By decomposing the mass with hydrochloric acid, the acid is set free. When pure, salicylic acid occurs as fine, white, prismatic, needle-shaped crystals, permanent in air, having a sweetish, slightly acrid taste and acid reaction; soluble in 450 parts of cold water and in 2.5 parts of alcohol. Its solutions give an intense violet color with ferric salts. This is used as a test. Salicylic acid is sometimes added to wines, beer, and other articles of food, as a preservative—a use which should be prohibited.

The **salicylates** of potassium, lithium, sodium, bismuth, and some of the alkaloids are used in medicine. The **salicylic esters** are very numerous, some of which are used in medicine, and have already been described.

Closely related to salicylic acid is a glucoside of oxybenzoic alcohol, called **salicin.**

$C_6H_4 \begin{cases} OH \\ CH_2OH. \end{cases}$
Oxybenzoic Alcohol.

$C_6H_4 \begin{cases} OH \\ CH_2O(C_6H_{11}O_5). \end{cases}$
Salicin.
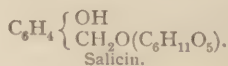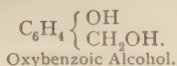
Salicin is found in the bark of different kinds of willow and poplar and in *castoreum*. It is prepared by boiling the bark with water and lead oxide, filtering, precipitating the lead with hydric sulphide, and evaporating the solution. The salicin separates from the solution in fine, colorless, needle-like prisms, having a very bitter taste and neutral reaction; soluble in 28 parts of water and in 30 parts of alcohol; insoluble in ether or chloroform; very soluble in hot water. When heated with acids it yields glucose and **seligenin.** It is used in medicine for the treatment of malaria.

Gallic acid, trioxybenzoic acid, $C_6H_2(OH)_3.CO.OH$, is prepared from gall-nuts by keeping them in a warm, moist place until

they undergo fermentation, extracting the mass with boiling water and crystallizing. It may be obtained from tannic acid by boiling with diluted acids or alkalies, or by spontaneous fermentation, as above described for gall-nuts.

Gallic acid crystallizes from water in fine, silky needles, readily soluble in three parts of boiling water, in ether and in alcohol. It gives a blue-black precipitate with ferric salts, and reduces the salts of silver, mercury, and gold. Its normal salts are permanent, but their solutions readily decompose. It has a strong astringent taste, and is used in medicine, in common with tannin, as a hemostatic and astringent.

ORGANIC BODIES CONTAINING NITROGEN.

Amins, Amids, Imids, Nitrils.

We have frequently spoken in these pages of **types** of compounds, especially of the **water type.** We now come to speak of compounds constructed upon the **ammonia type.**

Ammonia, $N \begin{cases} H \\ H \\ H \end{cases}$, is a type of a large number of organic compounds. An **amin** (or amine) may be regarded as formed from ammonia by replacing one or more of the H atoms by hydrocarbon radicals. The amins are divided into **monamins, diamins,** and **triamins,** accordingly as their molecules contain one, two, or three atoms of nitrogen. They are also classified into **primary, secondary, tertiary,** and **quaternary,** accordingly as one, two, three, or four atoms of hydrogen have been replaced. Quaternary substitution can only take place in NH_4OH, and gives rise to **ammonium bases,** instead of amins, as $N(CH_3)_4OH$, **tetramethyl-ammonium hydroxide.**

We may represent the different classes of amins as follows:

MONAMINS.

	Primary.	Secondary.	Tertiary.
$N \begin{cases} H \\ H \\ H \end{cases}$	$N \begin{cases} C_2H_5 \\ H \\ H \end{cases}$	$N \begin{cases} CH_3 \\ CH_3 \\ H \end{cases}$	$N \begin{cases} CH_3 \\ C_6H_5 \\ C_6H_5 \end{cases}$
Ammonia.	Ethylamin.	Dimethylamin.	Methyl-diphenylamin.

DIAMINS.

$N_2 \begin{cases} H_2 \\ H_2 \\ H_2 \end{cases}$	$N_2 \begin{cases} C_2H_4 \\ H_2 \\ H_2 \end{cases}$	$N_2 \begin{cases} C_6H_4 \\ C_6H_4 \\ H_2 \end{cases}$	$N_2 \begin{cases} C_2H_4 \\ C_2H_4 \\ (C_2H_5)_2 \end{cases}$
Condensed Ammonia.	Ethylenediamin.	Diphenylenediamin.	Diethylenediethyl-diamin.

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Amins all have basic properties, and, like NH_3, combine directly with acids to form salts.

Amids, Amic Acids, and Amido-acids.—An amid may be regarded as a compound formed from ammonia by the substitution of one or more acid radicals for hydrogen atoms. They are classified into **primary, secondary,** and **tertiary,** and into **monamids** and **diamids,** the same as the amins. The amids differ from the acids, from which they are formed, by having NH_2 substituted for the hydroxyl.

$$C_2H_3OOH. \qquad C_2H_3ONH_2. \qquad H_2O_2CO. \qquad (NH_2)_2CO.$$
Acetic Acid.   Acetamid.   Carbonic Acid.   Carbamid.
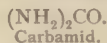
It is evident that a dibasic acid can form two compounds of this kind, according as one or both of the OH groups are replaced by NH_2. Where only one HO is replaced, it forms an **amic acid,** and when both are replaced it forms an amid :

$$\begin{matrix} H—O—C{=}O \\ H—O \end{matrix} \text{ forms } \begin{matrix} NH_2 \\ H—O \end{matrix}{>}CO \text{ and } \begin{matrix} NH_2 \\ NH_2 \end{matrix}{-}CO$$
Carbonic Acid.   Carbamic Acid.   Carbamid.

$$H_2O_2(C_2O_2) \text{ forms } \begin{matrix} H—O \\ NH_2 \end{matrix}{>}C_2O_2 \text{ and } \begin{matrix} NH_2 \\ NH_2 \end{matrix}{>}C_2O_2$$
Oxalic Acid.   Oxamic Acid.   Oxamid.
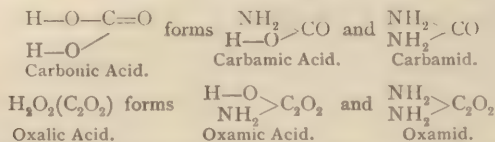
An **amido-acid** is a compound formed by replacing one or more H atoms in the radical of an organic acid by **amidogen,** NH_2.

Thus, amido-acetic acid has the composition, CH_2NH_2COOH.

The **imids** differ from amids in containing NH'', where the latter contain NH'_2. Thus, from carbonic acid we may have :

$$CO(NH_2)_2 \quad \text{and} \quad CONH.$$
Carbamid.   Carbimid.
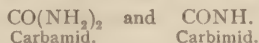
A **nitril** is a compound containing N united to carbon, and has been treated of elsewhere.

AMINS.

Of the large number of compounds which belong to this class of bodies, we can only mention a few in detail. As before mentioned, the amins are bases, or organic alkalies. They unite directly with acids to form salts, and their chlorides unite with platinic and auric chlorides to form double salts similar to those formed with ammonia. When heated with them, amins expel ammonia from its salts. The lower members of the group are gases, while the higher members are liquids or solids. The amins containing the lower alcohol radicals bear the closest resemblance to NH_3, but are even more strongly alkaline. In some cases they are caustic. They have an ammoniacal odor. They

precipitate the metallic salts, the precipitate being often soluble in excess of the reagent. The lower members are combustible gases, soluble in water. The solubility decreases as the number of carbon atoms increases. The ammonium bases—*i. e.*, those compounds which resemble NH_4OH in constitution—are solid, hygroscopic, and resemble KOH in properties. Some of the amins occur in nature. The most of them, however, are products of synthesis. Methylamin and trimethylamin occur ready formed.

Preparation of Amins.—First: By treating the cyanate of the alcohol radical with a solution of KOH.

$$CNOC_2H_5 + 2KOH = C_2H_5NH_2 + K_2CO_3.$$
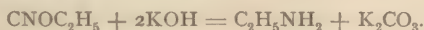
This reaction yields only primary amins.

Second: By heating a concentrated solution of ammonium hydroxide with the chloride, iodide, bromide, or nitrate of the radical.

$$\underset{\text{Ammonia.}}{NH_2H} + \underset{\text{Methyl-iodide.}}{CH_3I} = \underset{\text{Methylamin.}}{NH_2CH_3} + HI.$$

$$\underset{\text{Methylamin.}}{HI + NH_2CH_3} = \underset{\text{Methyl-ammonium Iodide.}}{NH_3(CH_3)I.}$$
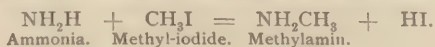
Treated with KOH, this compound gives methylamin.

$$NH_3CH_3I + KOH = \underset{\text{Methylamin.}}{NH_2CH_3} + KI + H_2O$$
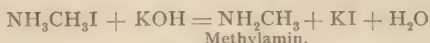
When methylamin is treated with CH_3I, it forms dimethyl-ammonium iodide.

$$CH_3I + NH_2CH_3 = NH(CH_3)_2HI.$$
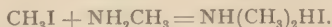
This, treated with KOH, gives $NH(CH_3)_2$. By treating these last compounds with a fresh quantity of CH_3I, we have the following:

$$NH(CH_3)_2 + 2CH_3I = \underset{\text{Tetramethyl-ammonium Iodide.}}{N(CH_3)_4I} + HI.$$
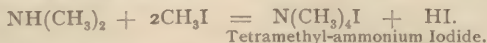
By using ethyl in the above series of reactions, in place of CH_3, we obtain a series of amins, in which C_2H_5 takes the place of CH_3. Numerous isomers exist among the amin bases. In reacting with acids, amins behave like NH_3, the ammonium bases like NH_4OH. The salts thus obtained are white, crystalline, frequently hygroscopic, and easily soluble in water. The chlorides form double salts with $PtCl_4$, similar to $2NH_4Cl.PtCl_4$.

Hydroxylamin.—NH_2O-H. This compound, closely related to ammonia, may be regarded as a molecule of ammonia in which one hydrogen atom has been replaced by the hydroxyl radical. It is prepared by treating tin with diluted nitric acid, or a mixture of this and

hydrochloric acid. The nascent hydrogen generated reduces the acid and forms the hydroxyl amin.

$$H-O-N\lessgtr^O_O + 3H-H = H-O-N = H_2 + 2H_2O.$$
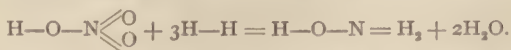
It is an unstable liquid, not obtainable in a free state, and possesses decided basic properties—*i. e.*, it colors red litmus paper blue and combines directly with acids to form salts.

$$\underset{\text{Hydroxylamin.}}{NH_2OH} + HCl = \underset{\text{Hydroxylamin Hydrochlorate.}}{NH_2OH.HCl.}$$
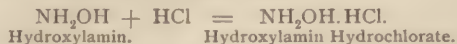
The hydrochlorate has been used as a local application in certain skin diseases, such as psoriasis, lupus, etc.

Methylamin, NH_2CH_3, occurs in certain plants (*Mercurialis perennis*), in the distillate from bones and wood, and in herring-brine. It is formed in many decompositions of nitrogenous bodies. It is more strongly basic than NH_3. It has a powerful ammoniacal odor, is soluble in water, and its solution behaves with metals like NH_4OH. It is a colorless, inflammable gas. One volume of water dissolves 1154 volumes of the gas. It forms a well-defined series of methylamin salts with the acids, which are generally crystallizable and soluble in water.

Dimethylamin, $NH(CH_3)_2$, occurs in Peruvian guano and in pyroligneous acid.

Trimethylamin, $N(CH_3)_3$, is pretty widely distributed in nature, is found in herring-brine, chenopodium, arnica-flowers, and the blossom of the pear. It also occurs naturally in cod-liver oil, guano, human urine, in ergot, and many flowers. It has been discovered in the residue from the evaporation of water contaminated with sewage. Trimethylamin occurs in yeast, and is frequently obtained by the distillation of distillery waste. It may be prepared by the action of potassium hydroxide on many vegetable substances, such as alkaloids, etc. It is an oily liquid, having a disagreeable odor, a strongly alkaline taste, and is soluble in water, alcohol, and ether. It combines with acids to form crystallizable salts. The three methylamins, above described, accompanied by smaller quantities of other amins, are produced by the putrefactive decomposition of animal matters.

Propylamin, $NH_2C_3H_7$, is a colorless liquid, boiling at 50° C. (122° F.). Its hydrochlorate has been used in medicine.

Tetramethyl-ammonium hydroxide, $N(CH_3)_4OH$, is obtained by decomposing the corresponding iodide, $N(CH_3)_4I$. It is a crystalline solid, very soluble in water, and resembling ammonium hydroxide. It forms crystallizable salts with acids.

Cholin, trimethyl-oxethyl-ammonium hydroxide, $N(CH_3)_3$-$(C_2H_5O)OH$, occurs in combination in the human body, in the complex substance known as lecithin. It was first discovered among the decomposition products of the bile. It is a colorless fluid of oily consistency, possesses a strong alkaline reaction, and forms deliquescent salts with acids. The salts with HCl, $PtCl_4$, and $AuCl_3$ are the most important. Cholin is a most unstable body, the mere heating of its aqueous solution sufficing to split it up into glycol, trimethylamin, and ethylene oxide. It may be prepared from the yolks of eggs by decomposing the residue left after complete extraction of the substance with alcohol, by boiling it for an hour with BaO_2H_2. The Ba compound is decomposed with CO_2, and the cholin precipitated from this solution with $PtCl_4$. By oxidation with nitric acid it yields an extremely poisonous alkaloid, **muscarin,** $C_5H_{15}NO_3$. Cholin itself is more or less poisonous, and is now recognized as one of the ptomaines which occur in putrefying animal matters.

Neurin, Trimethyl-vinyl-ammonium Hydroxide.—NOH-$\left\{\begin{array}{l}(CH_3)_3 \\ C_2H_3\end{array}\right.$ This substance is closely related to cholin, both in composition and origin. It is a decomposition product of lecithin and protagon, and is formed by the putrefactive decomposition of animal tissues. It is one of the alkaloidal bodies known as ptomaines. It is, like cholin, a syrupy fluid with a strong alkaline reaction, and is extremely soluble in water. It forms double salts with platinum and gold, similar to those of cholin. Neurin is a much more powerful poison than cholin.

Muscarin, $NOH(CH_3)_3C_2H_3OH_2O$, is closely related to cholin and neurin. It occurs in the poisonous mushroom, *Agaricus muscarius*, and is produced during the putrefactive decomposition of albuminoid substances. The free alkaloid forms very deliquescent, colorless, odorless, tasteless, and strongly alkaline crystals. It is soluble in water and alcohol in all proportions, sparingly soluble in chloroform, and insoluble in ether. It is a more powerful base than ammonium hydroxide, and forms a series of salts. Like cholin and neurin, it is a very active poison. The symptoms of muscarin poisoning are salivation, vomiting and diarrhea, contraction of the pupils, diminution of the rapidity of the pulse, interference with respiration and locomotion, gradual depression of the heart's action, and finally death. Atropine is physiologically antagonistic to muscarin, and diminishes its intensity of action.

Phenylamin, or **anilin,** $NH_2C_6H_5$, is the best-known amin. It is obtained from benzene by first converting this into nitrobenzene, by the action of a mixture of concentrated nitric and sulphuric acids.

$$C_6H_6 + HNO_3 = C_6H_5NO_2 + H_2O.$$
$$\text{Benzene.} \qquad\qquad \text{Nitrobenzene.}$$
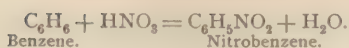
Nitrobenzene is generally a pale yellow, strongly refractive liquid, boiling at 220° C. (428° F.). It has a burning, sweet taste, and an odor resembling that of bitter almonds and cinnamon. It is used in perfumery under the name of **essence of mirbane.** It is a violent poison. When treated with nascent hydrogen, generated by zinc and acetic or hydrochloric acid, **anilin** is produced.

$$C_6H_5NO_2 + 3H_2 = C_6H_5NH_2 + 2H_2O.$$
$$\text{Nitrobenzene.} \qquad\qquad \text{Anilin.}$$
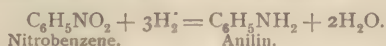
The anilin combines with the acid present, forming a crystallizable salt. Like all the amins, it acts as a base, uniting directly with acids.

Anilin is, when pure, a colorless, oily, refractive liquid, boiling at 182° C. (359° F.), and is insoluble in water. It is the basis of a large number of beautiful coloring matters, very much employed in dyeing and calico printing. In 1858 Perkins obtained a purple dye, by acting upon anilin oil with potassium dichromate and sulphuric acid. Other colors were soon obtained ; greens, yellows, reds, blues, violets, and black have all been obtained from anilin. These dyes are soluble in alcohol and glycerin, and are used for a variety of purposes.

Anilin is easily detected by a solution of sodium hypochlorite (chlorinated soda), with which it gives a purple-colored solution. Anilin is a powerful antiseptic, especially in its action on the tubercular bacillus.

Anilin is a powerful narcotic poison, whether taken internally or inhaled as a vapor. The salts, when pure, are comparatively innocuous.

Diamins.—Few of the diamins known are of importance to the physician or pharmacist. Some of them have been discovered among the products of the putrefaction of albuminoid substances, and it is quite probable that some of the natural vegetable alkaloids belong to this class of bodies.

Piperazine, Diethylenediamin.—$N_2 \begin{cases} H_2 \\ (C_2H_4)_2 \end{cases} = C_4H_{10}N_2.$ This is a synthetical compound recently introduced as a solvent for uric acid. It is prepared by the action of ammonia on ethylene bromide or chloride.

The reaction is complex, giving salts of a number of bases. When this product is distilled, it yields a distillate between 130° C. and 180° C. (266° F. to 356° F.), from which diethylenediamin separates.

By the action of a nitrite, this is converted into a dinotroso-piperazine.

This substance, when treated with HCl, evolves nitrous fumes, and forms hydrochlorate of piperazine.

Piperazine is a white, lustrous, crystalline solid, melting at 104° C. to 107° C. (219.2° F. to 224.6° F.) and boiling at 145° C. (293° F.).

It is very soluble in water. It absorbs water and CO_2 from the air and becomes liquefied. The aqueous solution is nearly tasteless and has a strong alkaline reaction.

The compound which it forms with uric acid is seventeen times more soluble than lithium urate, it being soluble in fifty parts of water. It is not decomposed in the body, and is excreted in the urine as a neutral urate.

AMIDS.

The **amids** differ from the amins in having an acid radical where an amin has a hydrocarbon radical. They may be primary, secondary, or tertiary. They may be monamids, diamids, or triamids. The primary monamids containing radicals of the fatty acid series are solid, crystallizable bodies, neutral in reaction, volatile without decomposition, and are usually soluble in alcohol and ether. They unite with acids to form salts. They also unite with certain alkaline hydroxides to form metallic salts.

Formamid, NH_2CHO, is a colorless liquid, soluble in water and alcohol, boiling at 192° C. (377.6° F.) with partial decomposition. It is prepared by heating ethyl-formate with an alcoholic solution of ammonia, or by the dry distillation of ammonium formate. It combines with chloral to form a compound which has been introduced into medicine as a hypnotic under the name of **chloralamid.**

Chloralamid, chloral-formamid, $NH \begin{cases} CHO \\ CCl_3CH_2O \end{cases}$, is a compound formed by the direct combination of equal molecules of formamid and chloral. It occurs in the form of colorless, odorless, faintly bitter crystals, fusing at 115° C. (239° F.), and is sparingly soluble in water. It requires about 20 parts of cold water, or $1\frac{1}{2}$ parts of 96 per cent. alcohol, to dissolve 1 part of the substance. Hot water decomposes it into chloral hydrate and ammonium formate. The same effect is produced by alkalies, but not by dilute acids. It is employed as a hypnotic in from 10- to 40-grain doses.

Urea, carbamid, $(NH_2)_2CO$, is the chief nitrogenous constituent of urine. The urine of birds contains a small quantity. When on a mixed diet the average normal human urine contains from 2.5 to 3.5 per cent., the average daily excretion being about 30 gm. It is also found in minute quantities in normal blood, serous fluids, lymph, per-

spiration, and the aqueous humor. It is also met with in the liver. It crystallizes from a concentrated solution in the form of long, thin, glistening, needle-shaped crystals. If deposited slowly, it forms four-sided prisms with pyramidal ends. They are anhydrous. Urea is very soluble in cold water, less soluble in alcohol, and insoluble in pure ether and petroleum ether. It possesses a somewhat bitter, cooling taste, resembling that of saltpeter. It may be prepared from the urine by concentrating to a syrup, extracting the residue with boiling alcohol, and concentrating the alcoholic extract by slow, spontaneous evaporation, until the urea crystallizes out. It is then purified by recrystallization from alcohol, decolorizing with charcoal if necessary. Or, the urea may be precipitated as nitrate by the addition of nitric acid to the concentrated and cooled urine. The nitrate is then decomposed by suspending it in water and adding barium carbonate. The urea is then crystallized as before. It may be prepared synthetically in several ways. The most convenient method is by mixing equal quantities of ammonium sulphate and potassium cyanate. The ammonium cyanate thus formed, on being evaporated to dryness, is transformed into urea, $NH_4CON = NH_2CONH_2$. This synthesis was performed by Wöhler in 1828, and was the first substance of animal origin that was artificially prepared, and may be regarded as the beginning of synthetic chemistry. Urea forms well-defined salts with both bases and acids. The nitrate, $(NH_2)_2CO.HNO_3$, is easily obtained from urine by evaporating it down to about one-fourth its volume, adding pure nitric acid, and keeping the solution cool. The crystals will separate in a few minutes in the form of rhombic tables, frequently aggregated into masses. The crystals are only slightly soluble in HNO_3 or alcohol, but are soluble in water. The oxalate of urea crystallizes out in rhombic tables, closely resembling those of the nitrate, and under the same conditions. Of the many salts which urea forms with bases and salts, that which it forms with mercuric nitrate is important, because this salt is used as a reagent for the quantitative estimation of urea. When a solution of mercuric nitrate is added to one of urea, a precipitate is formed as long as urea remains in solution. Urea may be heated dry to about 120° C. (248° F.) without decomposing, but at about 132.6° C. (271° F.) it gives off ammonia, and at 150° C. (302° F.) it is converted largely into biuret.

$$2(NH_2)_2CO = NH_2CONHCONH_2 + NH_3.$$

On heating to a higher temperature,—about 200° C. (392° F.),—it is largely converted into cyanuric acid. When boiled in water with dilute H_2SO_4 or alkalies, it gradually absorbs two molecules of water,

and is converted into carbonic acid and ammonia. A similar change is produced under the influence of certain micro-organisms, which are found in urine undergoing the alkaline fermentation. The best known of these is the micrococcus ureæ, from which a soluble hydrolytic enzyme may be extracted. The most prolific source of the urea enzyme is the mucous urine passed in inflammatory diseases of the bladder. In such cases the enzyme seems to be associated with mucin, and is presumably secreted by the mucous membrane. This explains why, in all inflammatory diseases of the bladder, the urine so readily undergoes the alkaline fermentation. When treated with nitrous acid, urea undergoes decomposition into CO_2, N, and H_2O. A similar decomposition is obtained by the action of NaOCl or NaOBr.

$$(NH_2)_2CO + 3NaBrO = 3NaBr + CO_2 + N_2 + 2H_2O.$$
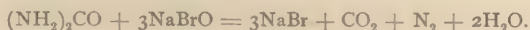
Since the volume of N evolved is constant for a given weight of urea, this reaction is made the basis of a method for the quantitative estimation of urea in urine. It may be detected in solution by evaporation with nitric acid or oxalic acid, and examining the crystals under a lens. Mercuric nitrate should give a precipitate in the absence of sodium chloride in excess. Yellow nitrous acid should produce an effervescence. With furfurol and hydrochloric acid, in not too dilute a solution, urea gives a play of colors, passing rapidly from yellow through green, blue, violet, and finally purple. The estimation of urea will be considered in a chapter on the examination of urine.

The **origin of urea** in the body has been the subject of a great deal of discussion and experiment. There is no doubt that its origin is in the decomposition of muscular and other tissues. The immediate antecedents of urea are not so clearly known. It is supposed, however, that creatin, creatinin, glycin, leucin, and other members of the amido-acid class are the intermediate products between the proteids on the one hand, and urea on the other. The seat of the changes of these amids into urea is supposed to be largely in the liver. In the case of leucin, the evidence of this is direct, and there is increasing evidence that this organ is largely concerned in the synthetic changes which lead to the formation of urea in mammals and of uric acid in birds. Schroeder has shown that the conversion of $(NH_4)_2CO_3$ into urea occurs in the liver, and Minkowski has shown a similar relation to the formation of uric acid in birds. When the liver is diseased, leucin and tyrosin escape conversion and appear in the urine, and at the same time there is a marked diminution in the excretion of urea. When urea is given to birds, it is eliminated as uric acid. These changes do not occur after extirpating the liver.

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DERIVATIVES OF ANILIN.

The remaining H atoms of the original ammonia, from which anilin is supposed to be derived, may be replaced by a considerable number of radicals. We may substitute Cl for the H, forming several isomeric **chloranilins**. In all such cases the N is assumed to be attached to C atom number one of the benzene ring. A large number of isomeric compounds are thus produced, none of which have been employed in medicine. The nitro- derivatives, which may easily be formed, are not employed in medicine. The **anilids** may be considered as a class of compounds in which one or more of the remaining H atoms in NH_3 have been replaced by an acid radical.

Acetanilid, antifebrin, $N \begin{cases} C_6H_5 \\ C_2H_3O \\ H \end{cases}$, differs from anilin in having

the radical of acetic acid substituted for one hydrogen atom. It is prepared by the distillation of anilin acetate, or by boiling anilin with glacial acetic acid.

It occurs in white, shining plates, melting at $112.8°$ C. $(235°$ F.$)$ and boiling at $292°$ C. $(558°$ F.$)$.

It is sparingly soluble in cold water, but is more freely soluble in hot water, from which it crystallizes on cooling. It is very much employed in medicine as an antipyretic—*i. e.*, to lower the bodily temperature in fevers. It is used in the arts for the preparation of derivatives of anilin.

It is prepared by the prolonged action of pure anilin upon glacial acetic acid at a high temperature, submitting the mixture to fractional distillation, collecting what passes over at $295°$ C. $(563°$ F.$)$, and recrystallizing from boiling water.

$$C_6H_5NH_2 + C_2H_3O_2H = C_6H_5NHC_2H_3O + H_2O.$$
$$\text{Anilin.} \qquad \text{Acetic Acid.} \qquad \text{Acetanilid.}$$
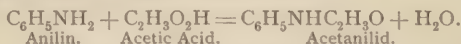
It is official in the U. S. P. and in several foreign countries. It is identified by the development of a yellow-green color, with a green florescence (flavanilin) when heated for some time with an equal weight of $ZnCl_2$. Acetanilid is only partly decomposed in the animal body, being excreted in the urine in the form of complex phenols. **Antifebrin** is the copyright name of acetanilid.

Methyl-acetanilid, exalgin, $N \begin{cases} C_6H_5 \\ C_2H_3O \\ CH_3 \end{cases}$, is produced by the substitution of CH_3 for H in acetanilid. It is formed by warming together methyl-anilin and acetyl-chloride. It occurs as a tasteless, crystalline powder, with a melting point of $100°$ C. $(212°$ F.$)$, and

boiling without decomposition at 240° to 250° C. (464° to 482° F.). It is readily soluble in alcohol, but with difficulty in water. It is employed in medicine for the relief of pain, and is best given in capsules or powders, in doses of one to four grains.

HYDRAZINS.

The hydrazins are a series of peculiar bases, mostly liquid, and closely resembling the amins. They differ from them in containing two atoms of N instead of one, and in their ability to reduce an alkaline copper solution (Fehling's), in most cases, even in the cold. They are derived from diamidogen, or hydrazin, NH_2NH_2, of which little is yet known. In hydrazin, as in ammonia, we may replace one or more of the H atoms with a hydrocarbon radical. If one H atom be replaced, we have a primary hydrazin; if two are replaced, we have a secondary hydrazin.

Thus, **ethyl-hydrazin**, $C_2H_5NH—NH_2$, is a primary hydrazin; **diethyl-hydrazin**, $(C_2H_5)_2=N—NH_2$, is a secondary hydrazin.

Phenyl-hydrazin, $C_6H_5NH—NH_2$, is a colorless, crystalline solid, melting at 23° C. (73° F.) to a colorless oil which boils at 233° C. (451° F.) without decomposition. It combines with HCl to form phenyl-hydrazin hydrochlorate, $C_6H_5N_2H_3HCl$, which forms white, crystalline plates. Like all hydrazins, it is characterized by its strong reducing power, reducing Fehling's solution in the cold. It is prepared by reducing diazobenzene chloride with $SnCl_2$ and HCl.

$$C_6H_5.N = N — Cl + 4HCl + 2SnCl_2 = C_6H_5.NH.NH_2.HCl + 2SnCl_4.$$
Diazobenzene Chloride.
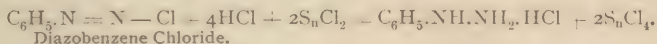
It is sparingly soluble in water, but soluble in alcohol and ether. It is important as an exceedingly delicate test for aldehydes and ketones, combining with them to form a class of bodies known as **hydrazones**, and with the sugars to form **osazones**. Most of these compounds are solid and crystalline, and may easily be recognized. They are employed in the separation of the sugars from one another. (See pp. 364 and 368.)

Hydracetin, pyrodin, acetyl-phenyl-hydrazin, $C_6H_5NH-NHCH_3CO$, is prepared by heating phenyl-hydrazin and acetic anhydride, dissolving the product in boiling water and crystallizing. It is also prepared by the prolonged action of glacial acetic acid on phenyl-hydrazin. It occurs as a white, tasteless, odorless, crystalline powder, melting at 128° C. (262.4° F.) and soluble in fifty parts of water. It has been recommended as an antipyretic and for external use in skin diseases. It is a well-marked blood-poison, destroying the blood-corpuscles. For this reason care must be exercised in its use.

Phenacetin, Acetphenetidin.—$N \begin{cases} C_6H_4\text{--}O\text{--}C_2H_5. \\ C_2H_3O. \\ H. \end{cases}$ As will be
seen from a comparison of the formulæ, this compound is closely
related to acetanilid. It is prepared from sodium paranitrophenol,
by converting it into paranitrophenetol by the action of ethyl-iodide.
This is reduced to paraphenetidin, which, on prolonged boiling
with glacial acetic acid, yields phenacetin. Phenacetin occurs as
colorless, tasteless, inodorous, glistening, scaly crystals, melting at
135° C. (275° F.). It is sparingly soluble in cold water, but soluble
in about seventy parts of hot water. It is more soluble in alcohol.
It is very much employed in medicine as an antipyretic, and for the
relief of pain, in doses up to fifteen grains. It has slight, if any, toxic
properties. It may be identified by the production of a deep-red
color with chromic acid, when added to the drug dissolved in diluted
hydrochloric acid. Its freedom from acetanilid may be proven if its
aqueous solution does not become turbid on the addition of bromine
water. Sulphuric acid should dissolve it without color. Heated with
free access of air, it burns off, leaving no residue.

Antipyrin, phenazone (Br.), **phenyl-dimethyl-pyrazolon,**
$C_6H_5N \begin{cases} COCH \\ NCH_3CCH_3 \end{cases}$, is prepared by the action of phenyl-hydrazin
on acetylactic acid, by which phenyl-hydrazin acetylactate is formed.
By the action of heat this separates into ethyl-alcohol and phenyl-
methyl-pyrazolon. By warming this compound with methyl-iodide,
a dimethyl-phenyl-pyrazolon is produced. Antipyrin forms small,
lustrous, rhombic needles, or plates, which are odorless and have a
bitter taste. It melts at 113° C. (235° F.), and is readily soluble
in water, alcohol, and chloroform, but it is less soluble in ether.
On exposure to the air it takes up a small quantity of water, and
thus melts at a lower temperature. It is decomposed by strong
NaOH solution, the base separating as a milky oil, speedily collecting
into globules. The aqueous solution exhibits no alkaline reaction
with litmus, but does so with methyl-orange. It may be quantita-
tively estimated by titration in an aqueous or alcoholic solution with
methyl-orange as an indicator. It is a strong univalent base. Its salts,
most of which are soluble, do not crystallize. Several of these salts
have been used in medicine. The benzoate, obtained by the addition
of antipyrin to a boiling solution of benzoic acid, has a pungent taste
and a slight odor of benzoic acid. It is slightly soluble in water, but
freely so in alcohol and ether. The salicylate, or **salipyrin,** is the
only one of these salts which has been much used in medicine. It is
prepared by the direct combination of antipyrin and salicylic acid.

It occurs as a white, coarsely crystallized, odorless powder, with a harsh, sweetish taste, almost insoluble in water, but readily soluble in alcohol, from which it crystallizes in hexagonal tables. It has been recommended as a remedy in the treatment of rheumatism. Antipyrin also forms compounds with phenol. **Phenopyrin** is prepared from equal parts of crystallized phenol and antipyrin. **Pyrogallopyrin, naphthopyrin,** and **resopyrin** are compounds of pyrogallic acid, naphthol, and resorcin, respectively, with antipyrin. Antipyrin forms several compounds with chloral. One of these has been used in medicine under the name of **hypnal. Iodopyrin** is a substitution product, in which one atom of H of the benzene nucleus has been replaced by iodine. The formula is $C_6H_4I-N\begin{cases} COCH \\ NCH_3CCH_3 \end{cases}$. It occurs as a tasteless, colorless, crystalline powder. It is slightly soluble in cold and readily in hot water.

Tests for the Anilin Derivatives.—Acetanilid and antipyrin are freely soluble in chloroform. Phenacetin, soluble in $CHCl_3$ with difficulty. Antipyrin is the only one freely soluble in water. Acetanilid, when heated with $CHCl_3$ and a few drops of strong solution of KOH, gives a disagreeable odor of phenyl-isonitril. Phenacetin and antipyrin do not give this reaction. Ferric chloride solution gives a red solution with antipyrin, disappearing on adding a few drops of H_2SO_4; it gives a red color **only on boiling** with acetanilid, exalgin, and phenacetin.

Acetanilid and antipyrin give precipitates from watery solution, with bromine water. Others do not.

Nitrous acid and sweet spirits of nitre give a green color with antipyrin, due to isonitroso-antipyrin.

AMIDO-ACIDS AND THEIR DERIVATIVES.

These compounds may be regarded as compounds formed by replacing a part of the hydrogen of a radical of an organic acid with amidogen. They exhibit both acid and basic properties. Many of these compounds and their derivatives exist in the human body. The simplest representative of the amido-acids is **glycocol, glycocin,** or **amido-acetic acid,** $N\begin{cases} H_2. \\ CH_2COOH. \end{cases}$ It may be prepared by heating monochloracetic acid with ammonia,

$$CH_2ClCO_2H + 2NH_3 = CH_2NH_2COOH + NH_4Cl,$$
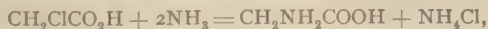
or by boiling glue with alkalies or acids. H_2SO_4 is added to the mass

to neutralize the alkali. It is then evaporated to dryness, and the residue exhausted with alcohol and allowed to crystallize. It may also be prepared from ox-bile, from uric acid, or by the action of formaldehyde upon a solution of hydrocyanic acid. $CH_2O + HCN + H_2O = NH_2CH_2COOH$. It forms large, colorless, transparent crystals, having a sweet taste and melting at 170° C. (338° F.), and decomposing at higher temperatures. It is sparingly soluble in cold water, but more soluble in warm. It is insoluble in alcohol and ether, and has an acid reaction. It combines with acids to form crystalline salts, which are generally decomposed by boiling water or by treatment with strong acids. When heated under pressure with benzoic acid, it forms hippuric acid. Its acid function is more marked than its basic. It expels carbonic and acetic acids from many of their salts. With ferric chloride, Fe_2Cl_6, it gives an intense red-colored solution, discharged by acids and returning on neutralization. It gives a characteristic copper salt, like most of the amido-acids. This salt serves for the separation of these acids.

Glycocol does not occur in the free state in the animal body, but enters into the composition of several important substances, more especially hippuric and glycocholic acids. It exists in combination in the gelatins, and in the bile as sodium glycocholate.

Hippuric Acid, Benzamidacetic Acid.—$N \begin{cases} COC_6H_5 \\ C_2H_2O.OH \\ H \end{cases}$

This acid is found in the urine of herbivorous animals, and in small quantity in human urine. When benzoic acid or oil of bitter almonds is taken internally, hippuric acid appears in the urine. It is generally prepared by evaporating the urine of the cow or horse to one-tenth its volume, and precipitating with hydrochloric acid. It forms large, rhombic prisms, soluble in hot, but sparingly in cold water; soluble in alcohol, but not in ether. The hippurates resemble the benzoates.

Methyl-glycocol, sarcosin, $N \begin{cases} H \\ CH_3 \\ CH_2COOH \end{cases}$, is found only in combination in the human body. It is of some interest as having been employed in experiments to determine the origin of urea in the body. It combines with cyanamid to form creatin. It, therefore, enters into the composition of creatin.

Taurin, amido-ethyl sulphonic acid, $N \begin{cases} H_2 \\ C_2H_4SO_2OH \end{cases}$, occurs in traces in the juice of muscles and of the lung. It is known chiefly as a constituent of taurocholic acid, one of the characteristic biliary

acids, especially of the carnivora. It crystallizes in colorless, four or six-sided prisms. It is readily soluble in water, less so in alcohol. Its solutions are neutral. It is a very stable compound, resisting a temperature of less than 240° C. (464° F.), and is not decomposed by diluted alkalies or acids, even on boiling. The metallic salts do not precipitate it. It may be prepared from ox-bile by boiling for several hours with diluted HCl. A resinous scum separates, and the bile acids are then precipitated from the liquid with lead acetate, the excess of lead being removed with H_2S. The filtrate from the PbS is concentrated and set aside to crystallize. It is purified by recrystallization. When taurin is introduced into the alimentary canal, the larger part appears in the urine in combination with carbamic acid as taurocarbamic acid. When injected subcutaneously, it is largely excreted in an unaltered form.

Creatin, Methylguanidinacetic Acid.—

$$N \begin{cases} -H \\ =C \\ \end{cases} \begin{matrix} N(CH_3).CH_2.COOH \\ \diagdown \\ NH_2 \end{matrix} = C_4H_9N_3O_2.$$ When sarcosin is
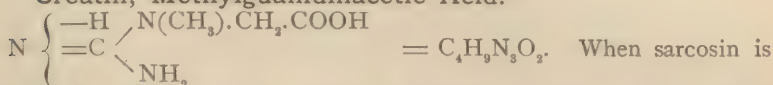
treated with cyanamid, creatin is produced. When cyanamid is treated with boiling baryta water, it takes up a molecule of water and forms urea.

$$\underset{\text{Cyanamid.}}{CNNH_2} + H_2O = \underset{\text{Urea.}}{CO(NH_2)_2}.$$
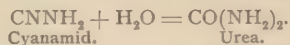
When creatin is similarly treated, it yields sarcosin and urea, showing the relation between urea and creatin, which body is probably one of the sources of urea in the human body. Creatin occurs characteristically in the muscles, and hence in meat-extracts. The amount is variable, but may be taken as from 0.2 to 0.3 per cent. of the weight of the muscle. It is also found in nervous tissues and in several other tissues of the body. It may also be found in the urine, where it is believed to be derived from creatinin. Creatin, when pure, forms white, opaque, colorless, transparent crystals. It is soluble in seventy-five parts of water, slightly soluble in alcohol, and insoluble in ether. Its solutions are neutral in reaction. Creatin is a weak base, forming crystalline compounds with some of the acids. It is most easily prepared from extract of beef, which is dissolved in water, precipitated with basic acetate of lead, filtered, and the lead separated from the filtrate with H_2S, concentrated at a moderate temperature to a syrup, and set aside to crystallize. As stated above, creatin may easily be derived from creatinin, and the reverse. Creatin very readily loses a molecule of H_2O, and thus becomes creatinin, $C_4H_7N_3O$. Creatinin occurs normally as a constant constituent of the urine, varying in amount from 0.5 to 4.9 gm. per day, according to

the amount of meat eaten. It crystallizes in colorless prisms or tables, according to the condition in which it is crystallized. It frequently assumes the peculiar whetstone shape of uric acid crystals. It is readily soluble in cold water and in alcohol, but is scarcely soluble in ether. Its solutions are usually alkaline, and it acts as a powerful base, forming compounds with the acids which crystallize well. It is precipitated from its solutions by $ZnCl_2$, in the form of a crystalline precipitate or warty lumps of aggregated crystals. This compound is formed whenever the solutions are brought together in a neutral and somewhat concentrated form. The addition of alcohol to the solution renders the precipitate more complete. This compound with $ZnCl_2$ is employed as a characteristic test for creatinin.

Leucin, amido-caproic acid, $C_6H_{13}NO_2$, is a product of the decomposition of proteids and gelatin, by either boiling acids, caustic alkalies, pancreatic digestion, or putrefactive fermentation. It occurs normally in variable amounts in the pancreas, spleen, thymus, thyroid, liver, and salivary glands; also in plants, such as bulbs, tubers, and seeds, where reserved material is stored. It is most easily prepared by pancreatic digestion of proteids, when it is produced in quantities of from 8 to 10 per cent. of the proteid digested, and is then always accompanied by tyrosin. It sometimes occurs in the urine, particularly in cases of acute yellow atrophy of the liver, although it does not always occur in this disease. Leucin forms yellow-brown spheres consisting of masses of needle-shaped crystals, soluble in water, slightly soluble in alcohol, and insoluble in ether. Under the microscope the spheres resemble fat-globules. When pure it forms very thin, white, glistening crystals. Leucin is very soluble in the presence of acids and alkalies, the acid solution being levorotatory, the alkaline solution being dextrorotatory. When heated, leucin decomposes into CO_2 and amylamin.

$$C_6H_{13}NO_2 = CO_2 + C_5H_{11}NH_2.$$

With HI it gives caproic acid and ammonia :

$$C_6H_{13}NO_2 + 2HI = C_6H_{12}O_2 + NH_3 + I_2.$$
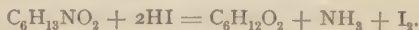
With H_2SO_4 it gives ammonia, NH_3, and valerianic acid. With potassium permanganate it gives oxalic acid, carbonic acid, valerianic acid, and ammonia. It is probable that similar decompositions occur in the human body. It is probably one of the intermediate products in the formation of urea from tissue proteids.

Tyrosin, Amido-oxyphenyl-propionic Acid.—Propionic acid has the formula $C_3H_6O_2$. Amido-propionic acid has the formula $C_3H_5NH_2O_2$. Oxyphenyl-propionic acid has the formula $C_3H_5(C_6H_4$-

OH)O$_2$. If another H in this formula be replaced by NH$_2$, we get C$_6$H$_5$OH.C$_2$H$_3$(NH$_2$)COOH, which is the formula of **tyrosin**. Tyrosin always accompanies leucin, though in less amount, as the product of the pancreatic digestion of proteids, but not of gelatin. It is also a product of the putrefactive decomposition of proteids and gelatin, as well as of the action of boiling mineral acids and alkalies. It is found normally in the pancreas and some other tissues. It occurs in the urine, together with leucin, in phosphorus poisoning, and in certain diseases of the liver, especially in yellow atrophy. It is also present, along with leucin, in many plant-tissues. Tyrosin crystallizes in very fine needles, usually collected together in feathery masses. The crystals are colorless, tasteless, and odorless. They are sparingly soluble in cold water, almost insoluble in alcohol, and quite insoluble in ether. They are readily soluble in acids and alkalies. It may be obtained, along with leucin, by boiling horn-shavings with H$_2$SO$_4$ (5 of acid to 13 of water). The H$_2$SO$_4$ is separated with lime, and the filtrate from the CaSO$_4$ evaporated down and crystallized. It is purified by recrystallizing from boiling water. When heated with Millon's reagent, tyrosin yields a brilliant crimson or pink coloration. If moistened on a watch-glass with strong H$_2$SO$_4$ and warmed for five or ten minutes on a water-bath, it forms tyrosin-sulphonic acid and turns pink.

Cystin, sulpho-amido-lactic acid, $S_2 <^{C(CH_3)(NH_2)COOH,}_{C(CH_3)(NH_2)COOH,}$ is a constituent of rare urinary calculi occurring in men and in dogs. It is occasionally found in the urine, from which it separates as a sediment on standing. It is prepared from this sediment, or from a cystic calculus, by solution in ammonia and crystallizing. It crystallizes in regular six-sided tablets, characteristic in appearance. It is insoluble in ether, alcohol, and water, but is readily soluble in NH$_4$OH. When boiled with NaOH, a sulphide of sodium is obtained, which gives a dark stain on silver coin.

Aspartic acid, C$_4$H$_7$NO$_4$, is **amido-succinic acid.** It is obtained from asparagin, which occurs in plants.

Carbamic acid, or **amido-formic acid,** NH$_2$CO.OH, is not known in the free state except mixed with ammonium carbonate in the commercial salt. Carbamic acid is of interest on account of the important part it is supposed to play in the formation of urea in the animal body. It may be formed by the direct union of dry NH$_3$ and CO$_2$, in the proportion of two molecules of the former to one molecule of the latter, thus:

$$2NH_3 + CO_2 = NH_4(CO_2NH_2).$$
Ammonium Carbamate.
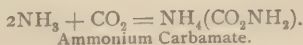
By simple dehydration this salt yields urea:

$$NH_4NH_2CO_2 - H_2O = H_2O + (NH_2)_2CO.$$
$$\text{Urea.}$$
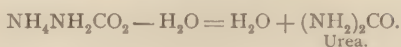
Ammonium carbamate is extremely soluble in water, in which solution it is gradually converted into the carbonate. When it is heated to 60° C. (140° F.), it decomposes into NH_3 and CO_2; but when heated under pressure at 130° to 140° C. (266° to 284° F.), it yields urea.
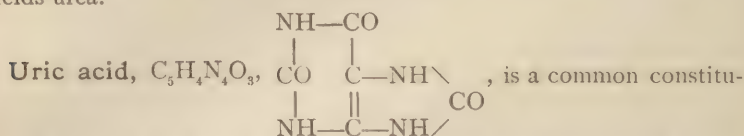
Uric acid, $C_5H_4N_4O_3$,
$$\begin{array}{c} NH-CO \\ | \quad | \\ CO \quad C-NH\diagdown \\ | \quad \| \qquad CO \\ NH-C-NH\diagup \end{array}$$
, is a common constitu-

ent of urine in birds and reptiles, and occurs sparingly in this secretion in men and most mammals. It is present also in the spleen, and traces have been found in various other tissues. It sometimes occurs as a concretion or calculus in the bladder and kidneys. In gout, accumulations of uric acid salts deposit in certain tissues, especially about the joints. When pure, it is a colorless, crystalline, tasteless powder without odor. Its crystalline form is very variable, the shape of the crystals depending upon the condition of the fluid at the time of crystallization. To the naked eye these crystals, when separated from the urine, always appear reddish or yellow in color, but under the microscope they appear to be colored yellow throughout. Uric acid is remarkably insoluble in water, 1 part requiring 15,000 parts of cold water and 1600 parts of boiling water to effect solution. It is insoluble in ether and alcohol. H_2SO_4 dissolves it in the cold without decomposition, as do also many of the alkaline salts and the caustic alkalies. Ammonia, however, does not dissolve it. It is fairly soluble in glycerin, and to some extent in solutions of lithium carbonate. It occurs in the urine also in the form of the neutral and acid urates of sodium, —the latter of which appears as a sediment,—which are frequently spoken of as **lithates,** and the term **lithic acid** is sometimes employed instead of uric acid. In urine that has undergone alkaline fermentation, ammonium urate will frequently be found, occurring in the form of small, brown, nearly opaque balls with radiating spicules, easily seen with a microscope of moderate power. The amount of uric acid in human urine is very small. Pathologically, it is found in considerable quantities. It may be prepared from human urine by adding from two to three per cent. of strong HCl, and allowing the solution to stand for twenty-four hours in a cool place. The crystals form on the sides and bottom of the containing vessel, and may be

filtered out. It is usually prepared from guano or snake-excrement. From the latter it is obtained by boiling with 1 part of KOH to 20 of water, as long as NH_3 is evolved, when the solution is filtered. On cooling, CO is passed through the solution, when the acid urate of potassium precipitates. This salt is dissolved in KOH and carefully neutralized with HCl, when the uric acid precipitates.

For methods of detection and estimation, see chapter on Urine.

Uric acid contains the nucleus of two molecules of urea, and is sometimes regarded as a diureid. In some of its decompositions, it yields urea as one of its products. For this reason it was formerly believed to be one of the antecedents of urea, and to be a stage in the oxidation of nitrogenous waste short of that necessary to produce urea. It is now believed to be derived from the xanthin bases, and these are derived from nuclein. By the oxidation of uric acid with nitric acid, it decomposes into a molecule of alloxan and one of urea. By further oxidation, alloxan is converted into **parabanic acid,** or **oxalyurea** and CO_2.

$$C_5H_4N_4O_3 + O + H_2O = C_4H_2N_2O_4 + (NH_2)_2CO.$$
$$\text{Uric Acid.} \qquad\qquad\qquad \text{Alloxan.} \qquad \text{Urea.}$$
$$C_4H_2N_2O_4 + O = C_3H_2N_2O_3 + CO_2.$$
$$\text{Alloxan.} \qquad\qquad \text{Parabanic Acid,}$$
$$\text{or Oxalyurea.}$$
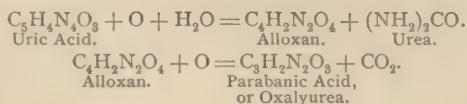
When parabanic acid is heated with alkalies, it forms oxaluric acid, and this by prolonged boiling is converted into urea and oxalic acid. By oxidation with $K_2Mn_2O_8$, uric acid is decomposed into allantoin and CO_2. Allantoin with HNO_3 gives urea as one of its decomposition products.

Oxaluric acid, $C_3H_4N_2O_4$, occurs in minute traces in human urine, and is a white, crystalline powder, not very soluble in water. Its alkaline salts, however, are readily soluble.

Allantoin, $C_4H_6N_4O_3$, is a characteristic constituent of the allantoic fluid and of the amniotic fluid. It is also found in the urine of many animals for a short period after their birth. It is found in the urine after the internal administration of uric acid. It has been found also in vegetable tissues. It crystallizes in small, shining, colorless, hexagonal prisms.

Alloxan.—$C_4H_2N_2O_4$. This is one of the decomposition products of uric acid under mild oxidation. It has been found in the intestinal mucus in cases of diarrhea. It crystallizes in colorless crystals, readily soluble in water.

Murexid, ammonium purpurate, $C_8H_4(NH_4)N_5O_6$, is produced by the oxidation of uric acid, alloxan, guanin, and a number of other derivatives of uric acid, with a subsequent treatment with NH_4OH.

It is an ammonium salt of a hypothetical acid which has not yet been isolated. It is of a brilliant reddish-purple color, and is formed in the **murexid test** for uric acid.

Biliary Acids.—The bile contains the sodium salts of two amido-acids, and several acids derived from these by decomposition. The two acids contained in the bile are glycocholic and taurocholic acids.

Glycocholic acid, $C_{26}H_{43}NO_6$, occurs in bile as a sodium salt. The acid occurs in two forms, the one as fine, crystalline needles, and the other as an amorphous, resinous solid. It is monobasic. It is soluble in hydrochloric, sulphuric, and acetic acids, without decomposition; soluble in glycerin, slightly soluble in cold and readily in hot water; very soluble in alcohol and insoluble in ether. When boiled with alkalies or mineral acids, it splits up into **cholic acid** and **glycocin.**

$$C_{26}H_{43}NO_6 + H_2O = \underset{\text{Cholic Acid.}}{C_{24}H_{40}O_5} + \underset{\text{Glycocin.}}{C_2H_3NH_2O_2}.$$
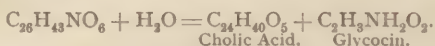
Taurocholic acid, $C_{26}H_{45}NSO_7$, occurs in small quantity in human bile, but in larger quantity in that of the carnivora. It is soluble in water and alcohol. With boiling alkaline or acid solutions it forms **cholic acid** and **taurin,** $C_2H_7NSO_3$. The spontaneous decomposition of bile causes the same change.

Both glycocholic and taurocholic acids form salts which have the power of dissolving cholesterin and of emulsifying fats. They also form insoluble compounds with the salts of the alkaloids and with peptone. These salts are soluble, however, in excess of the biliary salts. The taurocholate of morphine is crystallizable. The glycocholate of sodium exists in the bile, and may be prepared from fresh ox-bile. They may be precipitated from neutral solutions by lead acetate, but the precipitate is soluble in an excess of the precipitant.

Tests for Biliary Acids.—To a solution of the biliary acids add a few drops of a solution of cane-sugar (1 : 10), and then strong sulphuric acid. A cherry-red, followed by a deep purple-violet color is produced. This test, known as Pettenkofer's, can not be applied to organic mixtures, as urine, because numerous other bodies give the same color.

To apply it to such mixtures, evaporate to dryness, exhaust the residue with absolute alcohol, decolorize the solution with animal charcoal, evaporate to dryness, dissolve in water, and then test as above.

THE XANTHIN BODIES.

Under this heading we may place a group of animal bases, or **leucomains,** found in the juice of muscles, therefore found in "extract of beef," closely allied to uric acid, and which are believed to be the antecedents of this acid. They are believed to originate from

the decomposition of the nuclein of which the nuclei of animal cells are mostly composed. The group includes **adenin, guanin, xanthin, hypoxanthin, heteroxanthin, paraxanthin, carnin,** and **guanidin.** Similar bodies are also found in certain vegetable tissues, as caffeine, theobromine, etc. Their close relationship is shown by the ease with which they are converted, the one into the other. They are found most abundantly in conditions where there is an accumulation of leucocytes (white blood-cells) in the body. During cell-activity, or during rapid cell-disintegration, there appear about the cell the two bases, adenin and guanin.

$$\text{NH—CH}$$

Adenin, CH $\quad$ C—NH $\quad$ $= C_5H_5N_5$, is a base closely
$\qquad\qquad$ C=NH
$\qquad$ N — C = N
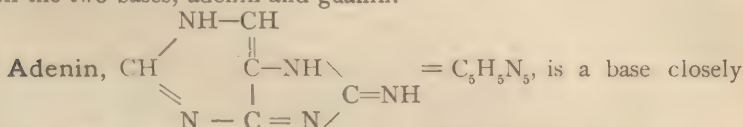
related to xanthin in composition, and was first obtained from the pancreatic tissue. It is said to have been found in the urine. A number of the above-mentioned compounds occur in the extract of meat. It has been proved that the chief virtue of extract of meat is in the stimulant properties of these bases.

$$\text{NH—CH}$$

Guanin, CO $\quad$ C—NH $\quad$ $= C_5H_5N_5O$, is found in Peru-
$\qquad\qquad$ C=NH
$\qquad$ NH—C = N
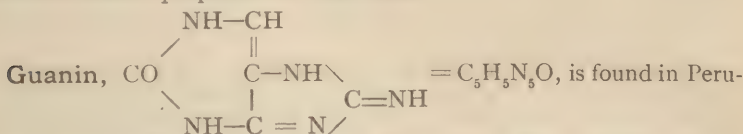
vian guano, and in small quantities in the pancreas, liver, muscle-extract, and many of the products of the action of acids upon nuclein. It may also occur in the urine. It is a white, amorphous powder, insoluble in water, alcohol, ether, and ammonia.

$$\text{NH—CH}$$

Xanthin, CO $\quad$ C—NH $\quad$ $= C_5H_4N_4O_2$, was first discovered
$\qquad$ NH—C=N—CO
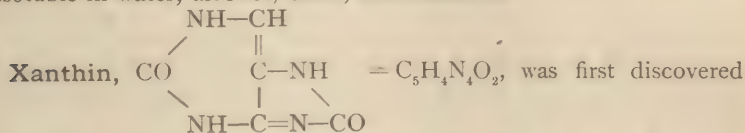
in urinary calculi and called xanthic oxide. It is a normal, though scanty, constituent of urine, muscle, liver, spleen, thymus, and brain-substance. It occurs in large quantities, together with hypoxanthin, in "extract of meat," and is also found in traces in certain vegetable tissues. In nearly all cases it is accompanied by hypoxanthin. It may be prepared from extract of beef. When pure, it is a colorless powder, almost insoluble in water, alcohol, and ether, but it dissolves readily in diluted acids and alkalies, forming crystallizable compounds.

$$
\text{Hypoxanthin, sarcin, } CH \underset{N - C = N}{\overset{NH - CH}{\diagup \overset{\|}{\diagdown}}} \underset{\diagup}{\overset{C - NH}{\underset{|}{\diagdown}} \underset{CO}{}} = C_5H_4N_4O, \text{ is}
$$
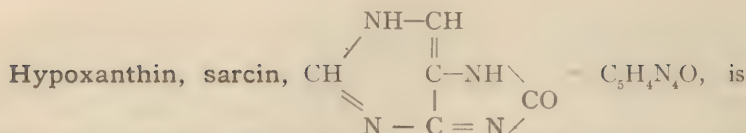
closely related to xanthin and usually occurs with it in the tissues and fluids of the body. It is obtained from meat extracts. The silver salts of xanthin and hypoxanthin are employed for their separation from fluids.

Methyl-xanthin, heteroxanthin, $C_6H_6N_4O_2$, occurs in minute quantities in the normal urine of man and dog, along with xanthin, hypoxanthin, and paraxanthin.

Dimethyl-xanthin, paraxanthin, $C_7H_8N_4O_2$, is an isomer of theobromine. As stated above, it occurs in very small amounts in urine, and is closely related to the above compounds. Its physiological action, when administered internally, is identical with that of theobromine.

$$
\text{Carnin, } CO \underset{NH - C = N - CO}{\overset{NH - CH}{\diagup \overset{\|}{\diagdown}}} \underset{\diagup}{\overset{C - NCH_3}{\underset{|}{\diagdown}} \underset{CHOH}{}} = C_7H_8N_4O_3, \text{ is another base}
$$
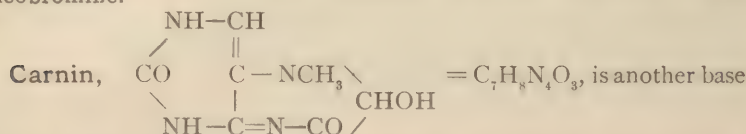
closely allied in composition to the above compounds. It occurs in extract of meat, of which it forms about one per cent. It may be prepared by precipitating extract of meat with BaO_2H_2 water, avoiding excess. The precipitate is filtered out, and the carnin precipitated from the filtrate with basic lead acetate. The precipitated lead salt is suspended in hot water, and the lead separated with H_2S; the filtrate is concentrated and the carnin crystallized out. It separates in white masses composed of very irregular crystals, readily soluble in hot water, slightly soluble in cold water, and insoluble in alcohol and ether. It unites with acids and salts to form crystalline compounds. Carnin may be converted into hypoxanthin by treatment with chlorine or HNO_3, or still more readily by bromine.

Caffeine and **theobromine,** described among the vegetable alkaloids, belong to the xanthin bases. Their relation to these bases will be seen from their graphic formulæ :

$$
\underset{NH - C - NCH_3}{\overset{NH - C}{\diagup \overset{\|}{\diagdown}}} \underset{C}{\overset{C}{\underset{\|}{}}} \underset{NCH_3}{} \underset{CO}{}
$$

Dimethyl-xanthin Theobromine.

$$
\underset{NCH_3 - C = N}{\overset{NCH_3 - CH}{\diagup \overset{\|}{\diagdown}}} \underset{C - NCH_3}{} \underset{CO}{}
$$

Trimethyl-xanthin Caffeine.
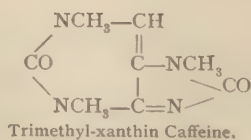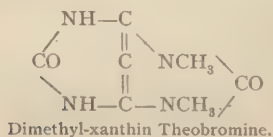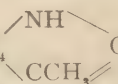
Guanidin, CN_3H_5, is one of the oxidation products of guanin. It does not occur in the free state in any of the normal tissues or fluids of the body, but has been obtained by the oxidation of proteids. It may be made to yield urea by treatment with hot dilute H_2SO_4. It has also been obtained by synthesis.
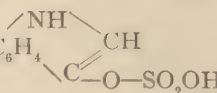
INDOL AND SKATOL.

Indol, $C_6H_4\genfrac{}{}{0pt}{}{\diagup NH\diagdown}{\diagdown CH\diagup\diagup}CH$, occurs characteristically in the feces. It is formed during the putrefactive decomposition of proteids, which usually occurs, to a greater or less extent, in the alimentary canal. A part of the indol is absorbed into the circulation, is oxidized to indoxyl, and appears in the urine as **potassium indoxyl-sulphate.** The remnant passes out with the feces. It may be obtained, together with phenol and skatol, by acidulating and distilling the products of a somewhat prolonged, alkaline, putrefactive, pancreatic digestion of proteids. Indol passes over with the distillate, from which it is extracted by shaking with ether, as an oily liquid, when the ether evaporates. It may also be prepared by heating most proteids with excess of KOH. Indol is a crystalline body, soluble in boiling water, alcohol, and ether. It may be detected as follows: A strip of pinewood, moistened with HCl, is colored a bright crimson when dipped into an alcoholic solution of indol. The alcoholic solution turns red when treated with nitrous acid. Its aqueous solution gives a red precipitate with the same reagent.

Skatol, methyl-indol, $C_6H_4\genfrac{}{}{0pt}{}{\diagup NH\diagdown}{\diagdown CCH_3\diagup\diagup}CH$, occurs also in human feces, together with indol, being present in larger amounts than the latter. It is supposed to give the peculiar fecal odor. The conditions of its production are the same as those for indol, so that the two substances occur mixed in the products of putrefactive decomposition of proteids, and of the action of caustic potash upon proteids at a high temperature. A portion of the skatol produced in the intestine is absorbed, oxidized, and appears in the urine as **potassium skatoxyl-sulphate.**

Indoxyl-sulphuric acid, $C_6H_4\genfrac{}{}{0pt}{}{\diagup NH\diagdown}{\diagdown C\!-\!O\!-\!SO_2OH}CH$, is the **indican** frequently mentioned as occurring in the urine. This compound is not identical with the indican found in plants, which is a glucoside.

It is in reality a sulphuric ether of indoxyl, C_8H_6NOH. Indican is increased in carnivorous animals under a meat diet, but is not increased by the administration of gelatin. It is more plentiful in the urine of herbivora than of carnivora. Indoxyl-sulphuric acid occurs in the urine combined mostly with potassium. When warmed with HCl it decomposes into indoxyl and acid potassium sulphate.

$$C_8H_6NOSO_2OK + H_2O = C_8H_6NOH + KHSO_4.$$
Potassium Indoxyl-sulphate.   Indoxyl.
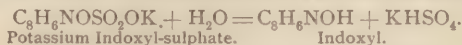
Indoxyl, by oxidation, is converted into indigo-blue.

$$2C_8H_6NOH + O_2 = C_{16}H_{10}N_2O_2 + 2H_2O.$$
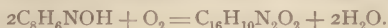
Indigo-blue, $C_{16}H_{10}N_2O_2$, is formed as above stated from indican, and gives rise to the blue color sometimes observed in sweat and urine. It may be obtained by slow formation from indican, in fine crystals, insoluble in water, but soluble in alcohol, ether, chloroform, and benzene. Indican is soluble in strong H_2SO_4, forming two sulphonic acids. The sodium salts of these acids are soluble in water, and, when mixed with sodium sulphate, constitute "indigo-carmine" of commerce; and in the pure form of sulphindigotate of soda is employed as a test for sugar in the urine. Indigo possesses a pure blue color, and leaves a red streak when drawn across a hard body. Treated with reducing agents in strongly alkaline solution, it is reduced to indigo-white; on exposure to air the indigo-white again becomes indigo-blue. This reaction proves a convenient one for the detection of indigo, or for reducing substances like dextrose. (See vegetable coloring matters, and chapter on Urine.)

ARTIFICIAL ORGANIC BASES.

The most of these bases may be regarded as aromatic hydrocarbons, in which one nitrogen atom has taken the place of the triad group CH'''.

The following graphic formulæ will show the relation of these bases to the corresponding hydrocarbons:
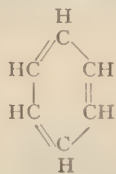
Benzene.
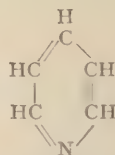
Pyridin.
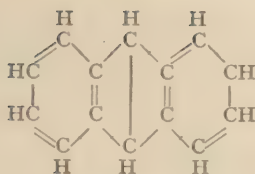
Anthracene.
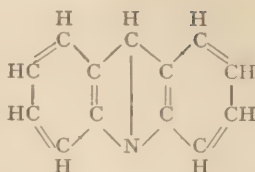
Acridin.
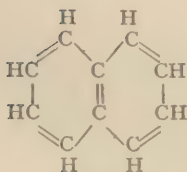
Naphthalene.
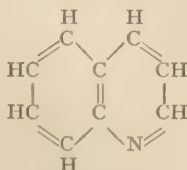
Quinolin.

The Pyridin Bases.—These artificial bases are produced by the decomposition of bone-gelatin, or ossein, in the destructive distillation of bones. They form a series of homologous bases which have received the name of pyridin bases. Some of them have also been found in coal-tar. They are liquids of a disagreeable, pungent, tarry odor, and belong to the tertiary monamins. They may be extracted from the offensive oil known as Dippel's oil, obtained from the distillation of bones. By the addition of or by shaking the oil with H_2SO_4, sulphates of the bases are produced which dissolve in water. The bases may be separated again on adding potash or soda. They are separated from one another by fractional distillation. The pyridin bases are often present in commercial ammonia. Their names, formulæ, and boiling points are as follows:

Boiling Points.		Boiling Points.	
Pyridin, C_5H_5N,	115° C. (239° F.)	Parvolin, $C_9H_{13}N$,	188° C. (370.4° F.)
Picolin, C_6H_7N,	133° C. (271° F.)	Coridin, $C_{10}H_{15}N$,	211° C. (411.8° F.)
Leutidin, C_7H_9N,	154° C. (309° F.)	Rubidin, $C_{11}H_{17}N$,	230° C. (446° F.)
Collidin, $C_8H_{11}N$,	170° C. (338° F.)	Viridin, $C_{12}H_{19}N$,	251° C. (483.8° F.)

Pyridin is obtained from Dippel's oil, and is also obtained synthetically from piperidin, which is itself derived from black and white pepper. It may be prepared synthetically by a number of reactions. It is a colorless liquid with a tarry odor and pungent taste. It is miscible with water in all proportions, and is hygroscopic. It forms salts with acids by direct addition, like the alkaloids; and, indeed, many of the alkaloids are believed to be salts of this base. It

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has been employed in medicine in 3- to 4-drop doses as a stimulant in heart disease. It has been used as a local application in diphtheria, and, by evaporation into the air, in the treatment of asthma. For medicinal uses, it should not be altered by exposure to light. Pyridin bases occur in tobacco-smoke.

Pyrrol, C_4H_5N, is a weak liquid base occurring in coal-tar and in Dippel's oil, from which it may be extracted by sulphuric acid and distilling from the sulphate with a stronger base. It possesses an odor similar to that of chloroform. By the action of the ethereal salts of iodine upon pyrrol, a **tetra-iodo-pyrrol**, C_4I_4NH, is obtained. This compound is used in medicine under the name of **iodol.**

Iodol occurs as a grayish-brown, odorless, tasteless powder. It is of a light yellow color when pure, and is more or less crystalline. It decomposes between 140° and 150° C. (284° and 302° F.) and evolves iodine vapors. It is soluble in alcohol and ether, but is sparingly so in water.

Derivatives of Pyridin.—Three isomeric methyl-pyridins are known under the name of **picolins,** and are found in coal-tar. β-methyl-pyridin may be prepared by distilling strychnine with lime. It is a liquid of unpleasant pungent odor. Dimethyl-pyridin, C_5H_3-$(CH_3)_2N$; trimethyl-pyridin, $C_5H_2(CH_3)_3N$; ethyl-pyridin, C_5H_4-$(C_2H_5)N$, and propyl-pyridin, $C_5H_4(C_3H_7)N$, are also known. Pyridin, like benzene, is capable of taking up six more hydrogen atoms, forming hexahydro-pyridin, or **piperidin,** $C_5H_5NH_6$, a colorless liquid having a peculiar, peppery odor. It is a strong base and forms a series of crystalline salts. Piperidin may be obtained, along with piperic acid, by treating piperine from pepper with an alcoholic solution of KOH.

Conine, $C_6H_4(C_3H_7)NH_6$, is propyl-piperidin. **Nicotine** is a hexahydro-dipyridyl, or formed from two molecules of pyridin. Dipyridyl has the formula $\begin{matrix} C_5H_4 \equiv N \\ | \\ C_5H_4 \equiv N \end{matrix}$, and nicotine the formula

$C_5H_4(H_6) \equiv N.$
$|$
$C_5H_4 \equiv N.$
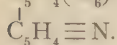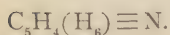
Quinolin Bases.—These are compounds which are generally derived from coal-tar, and are closely related to naphthaline. Bases similar to and isomeric with a few of these have been obtained by the distillation of some of the alkaloids with potash. **Quinolin,** or **chinolin,** C_9H_7N, has been prepared both from the alkaloids and from coal-tar. It has been prepared by the action of H_2SO_4 and nitrobenzene upon anilin and glycerin. The mixture is heated to

130° C. (266° F.), the heat removed when reaction begins, and then heated again for three hours, and finally distilled with lime, when quinolin distils over with anilin, from which it may be separated by fractional distillation. It may also be obtained by distilling quinine with an alkali. When pure, quinolin, or chinolin, is a color-less liquid, with a characteristic, aromatic, pungent odor, of sp. gr. 1.084. It is freely soluble in alcohol, ether, chloroform, and hot water. It is insoluble, or only slightly soluble, in cold water. It has been employed as an antiseptic and antizymotic, and as an antipyretic. For internal use a tartrate, salicylate, tannate, bisul-phate, and hydrochlorate have been recommended. When quinolin is treated with H_2SO_4, it yields a sulphonic acid. When this is treated with nascent hydrogen, and the resulting product with methyl-iodide, the body $C_9H_6(OCH_3)$ or $C_{10}H_9NO$, **methyl-oxyquinolin**, is produced. This substance closely resembles quinine, $C_{20}H_{24}N_2O_2$. Quinolin forms substitution products and hydrogen addition products. The hydroxyl derivatives are called oxyquinolins.

A number of derivatives of the oxyquinolins have found use in medicine.

NATURAL ORGANIC BASES, OR ALKALOIDS.

Many plants, and especially those having medicinal and poisonous properties, contain basic principles or compounds containing nitrogen, which are called **alkaloids**. Some are volatile, while others decom-pose when heated. Most of them resemble the amins in properties, while some correspond more nearly to the ammonium compounds. Most alkaloids are sparingly soluble in water, and more freely in alcohol, the solutions having a weak, alkaline reaction and bitter taste. They combine directly with acids, like NH_3, forming crystalline salts, which are generally soluble in water. Their hydro-chlorates form crystalline double salts with the chlorides of gold, platinum, mercury, etc. Most of them are precipitated by solu-tions of tannin, the double iodide of potassium and mercury, double iodide of cadmium and bismuth, phosphomolybdic, phospho-anti-monic, phosphotungstic, and picric acids, and by a solution of iodine in potassium iodide or hydriodic acid. These reagents are, therefore, used to precipitate the alkaloids from other substances found with them. By treating these precipitates with an alkaline hydroxide, the bases are separated.

PROPERTIES OF THE NATURAL ALKALOIDS.

The true vegetable alkaloids, or plant bases, are very numerous. Many of them are imperfectly known, while others have been studied very completely. The alkaloids are generally found in all parts of plants, though in some cases they are restricted to certain portions. The vegetable alkaloids are in many cases intensely poisonous, while others, as the alkaloids of coffee, cocoa, and cinchona, produce characteristic physiological effects, but are not actively poisonous. They generally have a bitter taste. Most of them are solid at ordinary temperatures. The non-oxygenized, volatile bases are liquid. The alkaloids are alkaline in reaction. They unite with acids to perfect neutrality, and form well-defined, crystallizable salts. In some cases the basic character is feeble, and even the salts with the stronger acids are easily decomposed. As a rule, the vegetable alkaloids, except the volatile bases, are sparingly soluble in water, and are, therefore, usually precipitated by the addition of a solution of a strong base to a solution of their salts. They are all readily dissolved by alcohol, except rheadine and pseudomorphine.

The salts of the alkaloids are generally more soluble in water than the bases themselves, and, as a rule, dissolve on the addition of alcohol. As a rule, the alkaloids form a class of double salts—*i. e.*, chloroplatinates, mercur-iodides, etc.—with platinic chloride and mercuric iodide. Immiscible solvents, such as chloroform, amyl-alcohol, ether, benzene, and bisulphide of carbon, differ considerably in their solvent powers for alkaloids and alkaloidal salts.

Nomenclature of Alkaloids.—While there is a great deal to be said in favor of the reform in spelling of many chemical terms, and while we have adopted the practice of dropping the final *e* in the artificial bases, amids, amins, etc., we shall retain the final *e* in the spelling of the names of the vegetable alkaloids. The alkaloids, being very active and frequently poisonous substances, should be sharply distinguished from the glucosides and bitter principles, and from the very numerous synthetical substances recently introduced into medicine. This distinction, which has existed for years, and which is well fixed in the minds of a large proportion of the physicians and pharmacists of all English-speaking countries, and preserved by the U. S. P. and Br. P., will be preserved by retaining the final *e*. Thus, we shall use *morphine* instead of *morphin*, and *quinine* instead of *quinin*.

Reagents for Precipitating Alkaloids.—Alkaloids, as a class, give precipitates with a considerable number of reagents, especially the compounds of the heavy metals. Of these precipitants, the most generally used are a solution of I in KI solution, a solution of

phosphomolybdic acid (Sonnenschein's reagent), and a solution of the double iodide of mercury and potassium (Mayer's reagent). With the exception of tannin, which should be employed in neutral or slightly alkaline solution, the precipitants of alkaloids are usually added to the solution slightly acidulated with H_2SO_4 or acetic acid.

Mayer's reagent is made by dissolving 13.546 gm. of mercuric chloride and 49.8 gm. potassium iodide in 1000 c.c. of water. This solution precipitates all alkaloids, forming white or yellowish-white, crystalline compounds of definite composition, for which reason this solution is used for the volumetric estimation of alkaloids.

Phosphomolybdic acid, mentioned above as a reagent for alkaloids, is prepared as follows: Dissolve 15 gm. ammonium molybdate in a little ammonia water and add water to make 100 c.c. This solution is poured into 100 c.c. of strong nitric acid, and this mixture is added to a warm five per cent. solution of sodium phosphate, as long as a precipitate forms. The precipitate is collected on a filter, washed, dissolved in a very little NaOH solution, and evaporated to dryness, or heated, until all NH_3 escapes. The residue is to be dissolved in about 10 parts of water, and enough HNO_3 added to redissolve the precipitate which at first forms. This reagent gives precipitates not only with alkaloids, but also with salts of ammonium and potassium.

Both of these reagents, while being delicate tests for alkaloids, precipitate albuminous and other matter not alkaloidal in nature.

Picric acid is employed as a saturated aqueous solution. It is very suitable for precipitating the cinchona bases, emetine, berberine, and veratrine.

Iodine dissolved in a solution of potassium iodide (**Wagner's reagent**) yields reddish or red-brown precipitates with nearly all alkaloids, even in very dilute solutions. The precipitates form more readily in solutions rendered slightly acid with H_2SO_4. Excess of the reagent should be avoided. This test is so generally successful in precipitating alkaloids that a negative reaction is conclusive proof of the absence of ordinary alkaloids, although precipitation is not absolute proof of the presence of an alkaloid. In alcoholic solutions the precipitates are deposited slowly, sometimes not at all, owing to their solubility in alcohol. The strength may vary within wide limits. A solution containing 20 gm. of iodine and 50 gm. of potassium iodide per liter is about the right strength.

Marme's reagent is a solution of the double iodide of potassium and cadmium. It is employed in solutions acidulated with H_2SO_4, and gives characteristic precipitates with many of the alkaloids.

The **double iodide of potassium and bismuth** (**Dragendorff's reagent**) is made by saturating a hot concentrated solution of potassium iodide with bismuth iodide, and then adding an equal volume of a cold, saturated solution of potassium iodide. It can not be diluted, but is applicable to solutions of alkaloids strongly acidulated with H_2SO_4.

Platinic chloride and auric chloride are frequently employed to precipitate alkaloids and to distinguish them from other bitter principles. Platinic precipitates have a yellow or yellowish-red color. The gold precipitates of a number of the alkaloids blacken, by reduction, on standing.

Color-reactions.—Many of the alkaloids give characteristic colors, when in the pure state, by treatment with certain reagents. These color-reactions are subject to variations, due to slight impurities, con-

COLOR-REACTIONS OF ALKALOIDS.

"O" indicates "*colorless.*"

ALKALOID.	PURE H₂SO₄.	H₂SO₄ +HNO₃.	H₂SO₄ +SUGAR.	FRÖHDE'S R.	HNO₃.	CONC. HCl.	H₂SO₄ +K₂Cr₂O₇.	Fe₂Cl₆.	OTHER REACTIONS.
Aconitine.	Grad. violet.	Grad. violet.	Fine red.	Yellow-brown.	Reddish brown.	O		In aq. sol. yellow ppt.	The phosphomolybdic acid precipitate rapidly turns blue.
Atropine.	O	O	O	O	O	O	Dis-colored.	Not pptd.	Dilates the pupil.
Berberine.	Olive-green.	Olive-green.		Brown-green.	Brown-red.				The addition of a few drops of chlorine water to a solution of berberine in not too small a quantity of hydrochloric acid produces a red color.
Brucine.	O	Red.	O	Red.	Red.	O	Orange.		Boiled with perchloric acid, a madeira color is developed. A solution in dilute sulphuric acid (1:8) is turned fine red by bichromate of potassium.
Caffeine.	O	O	O	O	O	O	O	Not pptd.	The residue obtained by dissolving in chlorine water and evaporating is colored red by ammonia.
Cinchonine.	O	O	O	O	O	O			Remains colorless when treated as above.
Cinchonidine.	O	O	O	O	O	O		Not pptd.	do.
Codeine.	O	Grad. blue.	Red.	Deep blue.	Yellow.	O	Olive-green.	O	Warmed with H₂SO₄ and Fe₂Cl₆, turns blue.
Colchicine.	Yellow.	Blue.	Yellow.	Yellow.	Blue.	O	Green, then brown.		If the blue color produced by adding salt-peter to the solution in H₂SO₄ is allowed to fade away, the residue is colored red by potash.
Coniine.	O	O	O	O	O	O			The hydrochloric acid solution leaves a crystalline residue when evaporated.

	Yellow-red.		Red.				Discolored.	Not pptd.	
Gelsemine.									Sulphuric acid and oxide of cerium color it cherry-red.
Hyoscyamine.	O	O	O	Violet.	Yellow.	O	Brown.	Blue.	Dilates the pupils.
Morphine.	Violet.	Violet.	Red.			O			Reduces iodates, nitrate of silver, ferri-cyanide of potassium, etc.
Narcotine.	Grad. rasp-berry.	Reddish-violet.				O			Fine red color is developed when the solution in dilute sulphuric acid is evaporated.
Nicotine.	O	O	O	O	O	O			The hydrochloric acid solution leaves an amorphous residue when evaporated.
Papaverine.	O	O			Orange.	O			Turns blue, warmed with sulphuric acid.
Physostigmine.	Grad. red.	Grad. red.			Red.	Reddish.			Solution of chloride of lime colors red. The precipitate with potassiomercuric iodide is soluble in alcohol. Physostigmine produces tetanus.
Pilocarpine.	O	O		Yellow, then brown.	Orange.		Green.	Ppt. in HCl sol.	
Piperine.	Grad. green.	Grad. green.							
Quinidine.	O	O	O	Greenish.	O	O			Like quinine.
Quinine.	O	O	O	Greenish.	O	O	Light yellow.	Not pptd.	The chlorine-water sol. is colored green by ammonia; red-brown with ammonia and ferricyanide of potassium.
Solanine.	Light reddish.	Light reddish.			Margin blue.				A hot mixture of equal volumes of alcohol and sulphuric acid is colored by solanine.
Strychnine.	O	O	O	O	O	O	Blue, passing quickly to violet and red.	Brownish-green ppt.	The blue coloration produced by H_2SO_4 and oxide of cerium is finer than with bichromate.

COLOR-REACTIONS OF ALKALOIDS.—*Continued.*

"O" indicates "*colorless.*"

ALKALOID.	PURE H₂SO₄.	H₂SO₄ +HNO₃.	H₂SO₄ + SUGAR.	FRÖHDE'S R.	HNO₃.	CONC. HCl.	H₂SO₄ +K₂Cr₂O₇.	Fe₂Cl₆.	OTHER REACTIONS.
Theobromine.	O	O	O	O	O	O	O	Not pptd.	Like caffeine.
Thebaine.	Blood-red.	Red.		Orange.	Yellow.	Yellow.			
Veratrine.	Grad. fine cherry-red.	Grad. fine cherry-red.	Grad. blue.	Grad. cherry-red.	Yellow.	Red.	Reddish-brown.	Ppt. in HCl sol.	

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centration, temperature, and by time. Color-reactions are, therefore, confirmatory rather than conclusive, and should always be confirmed by control tests upon a portion known to be the alkaloid in question. The reagents that are employed to give color-tests are : (1) **Concentrated sulphuric acid**; (2) **Fröhde's reagent**, concentrated sulphuric acid, containing molybdic acid (1 mgm. molybdic acid to 1 c.c. H_2SO_4); (3) **nitric acid**, sp. gr. 1.40 to 1.42 ; (4) **sulphuric acid, followed by a minute quantity of HNO_3 or KNO_3**; (5) **sulphuric acid** and **cane-sugar**. The dry substance to be tested is mixed with six parts of cane-sugar and a few milligrams of the mixture placed upon a drop or two of pure H_2SO_4 on a white plate.

The colors given by a number of the most important alkaloids, with some of these reagents, are given in a table on page 478.

Separation of Alkaloids.—The vegetable substance, the seed, bark, or leaf, is first disintegrated and extracted thoroughly with slightly acidulated water, which dissolves out the alkaloid. The volatile alkaloids are recovered from the solution, after the addition of an alkali, by distillation. Non-volatile alkaloids may be precipitated from an acid solution by an alkali, and the impure base thus obtained may be filtered out and dissolved in acids, and purified by recrystallization. Or, the precipitated alkaloids may be dissolved in alcohol, in which they are generally soluble, and the alcohol evaporated off. In some cases alcohol is employed for the extraction of alkaloids, as most of the alkaloids and alkaloidal salts are soluble in alcohol.

The separation and detection of alkaloids in organic mixtures, especially when present in small quantities, require an expenditure of considerable time and patience. When it is undertaken in toxicological examinations, it should only be by an expert who has made himself thoroughly familiar with the minutest details of the work. It should not be undertaken by any one without an adequate feeling of his responsibility. The general method employed in such cases is, in outline, as follows :

First. The substance to be examined is properly divided, or disintegrated, and digested at about from 40° to 50° C. (104° to 122° F.), with water slightly acidulated with H_2SO_4. After this digestion the solution is filtered and the filtrate evaporated over a water-bath to a thin syrup. This is then mixed with alcohol and digested for several hours at about 30° to 40° C. (86° to 104° F.), cooled, filtered, and again evaporated nearly to dryness. The alkaloids will be found in this residue as sulphates. A small quantity of water is now added, and the solution submitted to a series of immiscible solvents—first to the acidulated solution, and then to the same solution made alkaline. The acidulated solution is transferred from the evaporating vessel to a separating funnel, thoroughly and repeatedly shaken for a few minutes with freshly rectified petroleum ether, which should boil at about 65° to 70° C. (149° to 158° F.).

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The treatment is repeated until on evaporating a small portion of the ether it leaves no residue, showing that it ceases to dissolve anything. Petroleum ether removes mostly the coloring matter, etc., but none of the alkaloids.

Second. This same process is to be repeated with benzene, the boiling point of which is 81° C. (177.8° F.). This removes digitaline, cantharidine, and santonine, which are crystalline, and elaterine and colchicine, which are amorphous.

Third. The solution which has been treated as above is next shaken with chloroform, which removes cinchonine, digitaline, and picrotoxine. The chloroform is next dissolved out of the solution by again shaking with petroleum ether.

Fourth. The solution is now made alkaline with ammonium hydroxide, NH_4OH, and shaken with petroleum ether at a temperature of about 40° C. (104° F.), when in the petroleum ether will be found strychnine, quinine, brucine, veratrine, coniine, and nicotine if they are present.

Fifth. The solution is next shaken with benzene, C_6H_6, when any remaining strychnine, brucine, quinine, cinchonine, atropine, hyoscyamine, physostigmine, aconitine, codeine, and narceine will be dissolved out.

Sixth. Chloroform is next employed in a similar manner, which removes traces of morphine if this alkaloid be present.

Seventh. Amyl-alcohol is then employed in a similar manner, which dissolves morphine, solanine, and the glucoside salicin, if present.

Eighth. Evaporate the watery liquid with powdered glass and treat the residue with chloroform, when curarine, if present, will be extracted. After all these immiscible solvents have been separated, it then becomes necessary to isolate the residue by distillation of the solvent and, by proper tests, determine the alkaloid present.

The most important alkaloids, with their behavior with immiscible solvents, are given in tabular form on pages 484 and 485, with their formulæ. Of the volatile alkaloids, a few only are of importance.

VOLATILE ALKALOIDS.

Coniine, $C_8H_{17}N$, an alkaloid obtained from *Conium maculatum*, is a colorless, oily liquid, having an acrid taste and a disagreeable odor. It can be distilled when protected from the air. It boils at 170° C. (338° F.). It is sparingly soluble in water, but is more soluble in cold than in hot water, is soluble in all proportions in alcohol. It is soluble in six volumes of ether, and is soluble in most fixed and volatile oils. On exposure to the air, it becomes thick and resinous. It gives off vapors, at the ordinary temperature of the air, which form white fumes with HCl, similar to ammonia. It has been obtained synthetically from butyric aldehyde and alcoholic solution of ammonia. When heated with H_2SO_4, it gives a red color changing to green, and an odor of butyric acid. With nitrobenzene it gives a blue color changing to red and finally yellow.

Lobeline is a volatile liquid alkaloid found in *Lobeliæ inflata*. It has an odor and taste resembling that of tobacco.

Nicotine, $C_{10}H_{14}N_2$, occurs in tobacco. It is a colorless, oily liquid, which turns brown on exposure to light and air. It has a bitter, caustic taste, and a disagreeable penetrating odor. It distils at 250° C. (482° F.), and burns with a luminous flame. It is soluble in water, alcohol, ether, and the oils. It may be removed from its aqueous solution by shaking with ether. Its salts are deliquescent and crystallize with difficulty. It gives a violet color with HCl, and an orange with HNO_3. It is actively poisonous, producing death, when given in sufficient doses, sometimes with great rapidity.

Piperidine, hexahydropyridin, $C_5H_5N.H_6$, has been found in pepper, where it occurs as a decomposition product of piperine. It has been prepared synthetically. (See p. 474.)

Piturine, $C_{12}H_{16}N_2$, occurs in the dried leaves of *Duboisia Hopwoodii*, a plant growing in Australia and used by the natives to prepare a narcotic stimulant known as **pituri.**

Sparteine, $C_{15}H_{26}N_2$, is an alkaloid extracted from the common broom, *scoparius*.

It is a liquid, heavier than water, boiling at 288° C. (550° F.). It is sparingly soluble in water, giving an alkaline, bitter solution. It smells like anilin, and, like it, becomes brown on exposure to the air. The sulphate is used in medicine as a heart-stimulant.

NATURAL ALKALOIDS.*

NAME.	FORMULA.	SOLUBLE IN WATER.	AMMONIA WATER.	BENZENE.	ETHER.	CHLORO-FORM.	SOURCE.
Aconitine,	$C_{33}H_{45}NO_{12}$	S. in 150 pts.	S.S.	S.	S. in 2 pts.	S. in 2½ pts.	Aconitum napellus.
Atropine,	$C_{17}H_{23}NO_3$	S. in 60 pts.	S.	S. in 50 pts.	S. in 30 pts.	S. in 4 pts.	Atropa belladonna.
Apomorphine,	$C_{17}H_{17}NO_2$	Ins.	. .	S.	S.S.	S.S.	Morphine.
Berberine,	$C_{20}H_{17}NO_4$	S.S.	S.S.	. .	Insol.	S.S.	{ Berberis vulgaris. Calumba root.
Brucine,	$C_{23}H_{26}N_2O_4.4H_2O$	In 500 pts. boiling.	S.	S. in 60 pts.	Insol.	S. in 4 pts.	Nux vomica.
Caffeine,	$C_8H_{10}N_4O_2$	In 90 pts.	S.	S.	S. in 500 pts.	S. in 5 pts.	Coffee and tea.
Cinchonine,	$C_{19}H_{22}N_2O$	In 2500 pts. boiling.	Insol.	S.	S. in 400 pts.	S. in 60 pts.	Cinchona-bark.
Cinchonidine,	$C_{19}H_{22}N_2O$	In 2000 pts.	. .	. .	S. in 150 pts.	. .	Cinchona-bark.
Cocaine,	$C_{17}H_{21}NO_4$	In 704 pts.	. .	. .	S.	. .	Erythroxylon coca.
Codeine,	$C_{18}H_{21}NO_3$	In 75 pts.	In 75 pts.	S. in 12 pts.	S.	. .	Opium.
Colchicine,	$C_{17}H_{19}NO_5$	Soluble.	S.	S.S.	S.	S.	Colchicum autumnale.
Coniine,	$C_8H_{17}N$	In 100 pts.	S.	S.	S. in 6 pts.	S.	{Water-hemlock. Conium maculatum.
Delphinine,	$C_{24}H_{35}NO_2$	Insol.	S.	S.	S.	S.	Delphinium staphisagria.
Emetine,	$C_{28}H_{40}N_2O_5$	S.S.	S.S.	S.	Nearly insol.	Insol.	Ipecacuanha.
Ergotine. .	$C_{50}H_{62}N_2O_3$	S.	. .	. .	Insol.	. .	Ergot of rye.
Hydrastine,	$C_{21}H_{21}NO_6$	Insol.	S.S.	. .	S.S.	S.	Hydrastis canadensis.
Hyoscine,	$C_{17}H_{22}NO_4$	S.	. .	. .	. .	. .	. . .
Hyoscyamine,	$C_{17}H_{23}NO_3$	S. in hot.	S. in hot.	S.	S.	S.	Hyoscyamus niger.
Morphine,	$C_{17}H_{19}NO_3.H_2O$	S. in 500 pts. boiling.	S.S.	Insol.	Insol.	S. in 90 pts.	Opium.
Narceine, .	$C_{23}H_{29}NO_9$	S. in 200 pts. boiling.	S.S.	S.S.	Insol.	S.S.	Opium.
Narcotine,	$C_{22}H_{23}NO_7$	S. in 7000 boiling.	Insol.	S. in 25 pts.	S. in 120 pts.	S. in 3 pts.	Opium.
Nicotine, .	$C_{10}H_{14}N_2$	S.	S.	S.	S.	S.S.	Tobacco (tabacum).
Papaverine,	$C_{21}H_{21}NO_4$	Insol.	Insol.	S. in 40 pts.	S.S.	S.	Opium.

NAME.	FORMULA.	SOLUBLE IN WATER.	AMMONIA WATER.	BENZENE.	ETHER.	CHLOROFORM.	SOURCE.
Physostigmine (Eserine)	$C_{15}H_{21}N_3O_2$	S.S.	S.S.	S.	S.	S.	Calabar bean.
Pilocarpine, ...	$C_{11}H_{16}N_2O_2$	S. del.	S.S.	. .	Insol.	Insol.	Jaborandi.
Piperine, ...	$C_{17}H_{19}NO_3$	Nearly Insol.	. .	S.	S. in 90 pts.	S.	Cayenne pepper.
Piperidine, ...	$C_5H_{11}N$	S	S.	S.	. .	. .	Piperine.
Pseudomorphine, . .	$C_{17}H_{19}NO_4$	Insol.	Insol.	. .	Insol.	Insol.	Opium.
Quinine, ...	$C_{20}H_{24}N_2O_2.3H_2O$	S. in 1800 pts.	S.S.	S.	S.	S. in 50 pts.	Cinchona-bark.
Quinidine, ...	$C_{20}H_{24}N_2O_2$	S. in 750 pts.	. .	S.	S. in 30 pts.	S.	Cinchona-bark.
Rheadine, ...	$C_{21}H_{21}NO_6$	Insol.	Insol.	S.S.	S. in 1300 pts.	S.S.	Opium.
Sparteine, ...	$C_{15}H_{26}N_2$	S.S.	. .	. .	. .	. .	Broom-corn.
Strychnine, ...	$C_{21}H_{22}N_2O_2$	S. in 6500 pts.	S.S.	S. in 160 pts.	Insol.	S. in 7 pts.	Nux vomica.
Thebaine, ...	$C_{19}H_{21}NO_3$	Insol. (cold).	Insol.	S. in 18 pts.	S.	S.S.	Opium.
Theobromine, ...	$C_7H_8N_4O_2$	S. in 750 pts.	S.	S.S.	Nearly Insol.	S.S.	Cocoanuts.
Veratrine, ...	$C_{26}H_{43}NO_{11}$	S. in 10 o pts., hot.	S.S.	S.	S. in 12 pts.	S. in 2 pts.	Veratrum alba.

GLUCOSIDES.

Daphnin, ...	$C_{31}H_{38}O_{19}$	S.S.	S.	. .	Nearly Insol.	. .	Several species of daphne.
Digitalin, ...	$C_{10}H_{16}O_4$	S.S.	S.	S.	S.S.	S.S.	Foxglove (digitalis).
Picrotoxin, ...	$C_{20}H_{34}O_{13}$	S. in 50 pts.	S.	S.	S. in 250 pts.	S.	Cocculus indicus.
Salicin, ...	$C_{13}H_{18}O_7$	S.	. .	NearlyInsol	Insol.	. .	Willow-leaves.
Solanin, ...	$C_{43}H_{69}NO_{16}$	S. in 8000 hot.	Insol.	S.S.	S. in 4000 pts.	Insol.	Bittersweet.
Saponin, ...	$C_{32}H_{54}O_{18}$	S.	S.	. .	Insol.	. .	Saponaria officinalis.

* Largely from Prescott's "Prox. Organic Anal."
EXPLANATION.—S., soluble; S.S., slightly soluble. The numbers indicate the quantity of liquid required to dissolve one part of alkaloid.

NON-VOLATILE ALKALOIDS.

Properties of the Principal Non-volatile Alkaloids.—
Aconitine, Aconitina (Br.), $C_{33}H_{45}NO_{12}$, is a glacial mass or a white
powder, and crystallizes with difficulty in rhombic plates. It pos-
sesses a sharp, pungent taste, and, in general, the physiological prop-
erties of the plant.

The commercial alkaloid is probably a mixture of several alkaloids,
of which aconite-root contains at least nine. The alkaloid is very
poisonous and care should be exercised in tasting it. The most char-
acteristic test is the numbness of the tongue and lips, which it produces
in from one to fifteen minutes after tasting it. This numbness suffices
to detect as small a quantity as 0.01 of a milligram of the alkaloid.
It neutralizes acids, forming crystalline salts. It is precipitated from
its aqueous solutions by alkalies, phosphomolybdic acid, Mayer's re-
agent, and by iodine in KI solution. It is not precipitated by $PtCl_4$,
$HgCl_2$, or picric acid.

Apomorphine.—$C_{17}H_{17}NO_2$. When morphine is heated to 110°
C. (230° F.), with an excess of HCl and zinc chloride, it is converted
into apomorphine hydrochlorate.

Apomorphinæ hydrochloras (U. S. P., Br.) forms minute, gray-
ish white, bitter crystals, becoming greenish on exposure to light. It is
soluble in water and alcohol, and slightly soluble in ether and chloro-
form. It can also be prepared in the same way from codeine.

Atropine, daturine, atropina (U. S. P., Br.), $C_{17}H_{23}NO_3$, occurs
in belladonna and stramonium. It crystallizes in prisms, or stellated
tufts, white and fusible. It has a bitter taste, and dilates the pupil,
either when free or as salts. It is odorless. It is distinctly alkaline,
and neutralizes acids forming crystalline salts. **Atropinæ sulphas**
(U. S. P., Br.) appears as a white, crystalline powder, soluble in water.
It is an active poison, producing dryness of the throat, flushing of the
face, dilatation of the pupils, loss of speech and of muscular power,
dizziness, delirium, and coma. Fatal cases of poisoning are not fre-
quent. The treatment should consist in removing the unabsorbed
drug with the stomach-tube, after the administration of some liquid
containing tannin, as tea. A solution of atropine dropped into the
eye of a cat dilates the pupil. This is used as a test for the alkaloid.

Atropine belongs to a series of compounds called **tropeïnes,** and is
isomeric with **hyoscyamine and hyoscine.**

The other natural tropeïnes are belladonnine, atropamine, scopola-
mine, and benzoyl-pseudotropine. They are all saponifiable by treat-
ment with acids or alkalies, and are split into an acid, generally tropic

acid, $C_6H_5C(CH_2)COOH$, and tropine, or pseudotropine, $C_5H_7(C_2-H_4OH)N.CH_3$.

Brucine, $C_{23}H_{26}N_2O_4.4H_2O$, accompanies strychnine in the seeds and bark of different varieties of *strychnose*, or nux vomica. It forms oblique prisms or plates. sparingly soluble in water, readily soluble in alcohol, chloroform, and amyl-alcohol, and which lose their water when dried in the air. It is intensely bitter, and has a strong basic reaction, forming crystalline salts. Its action in the economy is similar to that of strychnine, but less active. With strong nitric acid it gives a red, fading to yellow, color; $SnCl_2$ changes the above red color to violet. Chlorine water colors it a bright red, which is changed to yellow-brown by NH_4OH.

Caffeine, theine, guaranine, caffeina (U. S. P., Br.), $C_8H_{10}-N_4O_2.H_2O$. White, silky needles; fuses and sublimes; has a faint bitter taste; poisonous in large doses; o. 4 to o. 5 gr. produces death in cats and rabbits. It exists in coffee, tea, and some other plants. Hot, fuming HNO_3 turns it yellow, which, after evaporation and treatment with NH_4OH, becomes purple (murexid).

Caffeine citrate, caffeina citrata (U. S. P., Br.), is defined as a weak compound of caffeine and citric acid, but it is probably a mere mechanical mixture.

It is a white powder having an acid taste and reaction. It is soluble in about twenty-five parts of water. Its physiological properties are the same as those of the alkaloid.

Cinchona Alkaloids.—Cinchona-bark contains a considerable number of alkaloids, several of which are employed in medicine. No less than thirty-three of these alkaloids have been isolated. They exist chiefly, though not wholly, in the bark, and are remarkable for their valuable antiperiodic and febrifuge properties. They all have well-defined basic characters, and their salts are usually crystallizable. Their basic character is such that they may be estimated by titration with a standard acid. They are but slightly soluble in water, but dissolve more readily in alcohol, and very easily in ether and chloroform. The latter liquids will remove them from ammoniacal solutions by agitation, but will not from a solution acidulated with H_2SO_4 or HCl. A solution of these alkaloids in H_2SO_4 exhibits a characteristic strong blue fluorescence. They are precipitated by the fixed alkalies, alkaline carbonates, or ammonia. The most important cinchona alkaloids are : quinine, quinidine, cinchonine, and cinchonidine.

Quinine, quinia, quinina (U. S. P.), $C_{20}H_{24}N_2O_2.3H_2O$, exists in the bark of the various species of the cinchona growing in the mountains of the northern part of South America. Different samples of the cinchona-bark vary in the contents of alkaloids. They vary from thirty-

three per cent. to as low as five per cent. It occurs as a white, flaky, amorphous, or crystalline powder, permanent in the air, and having a very bitter taste. It is soluble in 1670 parts of water and in six parts of alcohol. It is also soluble in chloroform, ether, carbon disulphide, benzene, ammonia water, and dilute acids. When treated at 100° C. (212° F.) it loses a part of its water of crystallization, but the remainder is expelled at 125° C. (257° F.). It has an alkaline reaction upon litmus paper, Brazil-wood, or methyl-orange.

A sulphate, bisulphate, hydrobromate, hydrochlorate, and valerianate are official. The tannate, salicylate, phenate, and numerous other salts are also employed in medicine.

Quinine sulphate, quininæ sulphas (U. S. P., Br.), $(C_{20}H_{24}N_2-O_2)_2H_2SO_4 \cdot 7H_2O$, is manufactured on a large scale for use in medicine. It is found in white, silk-like, needle-shaped crystals, somewhat flexible, making a very light and easily compressible mass, which effloresces in dry air, absorbs water in moist air, and becomes colored on exposure to light. It has a persistent, very bitter taste, and is not very soluble in water, but more readily in alcohol. It is soluble in 740 parts of water, 65 parts of alcohol, 40 parts of glycerin, and is freely soluble in dilute acids. When exposed to the air at a temperature of 100° C. (212° F.) for some hours, it loses all of its water of crystallization. The solution, especially in excess of H_2SO_4, exhibits a vivid blue fluorescence. The alkaloid is precipitated on the addition of ammonia water, but the precipitate is soluble in excess of ammonia. On treating 10 c.c of an aqueous solution of the salt with two drops of bromine water, and then with an excess of ammonia water, the liquid assumes an emerald-green color.

Quinine bisulphate, acid quinine sulphate, quininæ bisulphas (U. S. P.), $C_{20}H_{24}N_2O_2H_2SO_4 \cdot 7H_2O$, occurs as colorless, transparent, or whitish crystals or small needles, odorless, and having a very bitter taste. They are freely soluble in water, exhibiting beautiful blue fluorescence. It loses all of its water of crystallization at 100° C. (212° F.). It gives the same reaction with bromine water and ammonia as the sulphate.

Solution of iodine precipitates from the acetic acid solution of the basic sulphate a tourmaline-colored, crystalline body, with a green reflection.

The solutions of quinine and its salts are levorotatory. When dissolved in chlorine water, ammonium hydrate produces a deep emerald-green solution. If K_4FeCy_6 be first added, NH_4OH gives a deep-red color.

Quininæ hydrobromas, (U. S. P.), $C_{20}H_{24}N_2O_2HBr \cdot H_2O$; **quininæ hydrochloras,** (U. S. P., Br.), $C_{20}H_{24}N_2O_2HCl \cdot 2H_2O$;

quininæ valerianas (U. S. P.), $C_{20}H_{24}N_2O_2C_5H_{10}O_2.H_2O$, are offi-
cial. They occur as white, lusterless, odorless, silky needles, having
a very bitter taste.

Quinidine is isomeric with quinine, and is found with it. Quini-
dine is distinguished from quinine by its strong dextrorotatory power.
Quinicine is produced by the action of heat upon quinine, and does
not exist in the bark. Quinidine occurs in large prisms, soluble with
difficulty in water, but soluble in alcohol. It gives the same reaction
as quinine with chlorine and ammonia. It has a bitter taste and has
tonic properties similar to quinine, and its salts resemble those of
quinine. It is dextrorotatory. The sulphate is official.

Cinchona, cinchonine, cinchonina (U. S. P.), $C_{19}H_{22}N_2O$,
occurs in cinchona-bark, together with quinine and the other alkaloids.
It occurs in four-sided needles, fusing at 150° C. (302° F.). It is
soluble in 3810 parts of water and in 140 parts of alcohol. Its solutions
are dextrorotatory ; chlorine and ammonia give yellow precipitates ;
separated from quinine by insolubility in ether ; very bitter and has
less tonic properties than quinine. The sulphate is official.

Cocaine, $C_{17}H_{21}NO_4$, is one of the nine alkaloids which occur in
the leaves of *Erythroxylon coca*. It occurs in monoclinic, glistening
prisms. Heated with strong HCl, it decomposes. The hydrochlo-
rate has powerful anesthetic properties. Coca-leaves are used in Peru
as a stimulant. Its taste is at first bitter, producing paralysis of the
sense of taste and a consequent numbness of the tongue. When heated
with strong HCl, it decomposes into benzoic acid, methyl-alcohol,
and **ecgonine**, $C_9H_{15}NO_3$, a new base. Cocaine has been prepared
synthetically from ecgonine.

The hydrochlorate, $C_{17}H_{21}NO_4HCl$ (**cocainæ hydrochloras,** U.
S. P.), is the only official salt. It occurs as colorless, transparent
crystals, having a bitterish, saline taste, and producing on the tongue
a tingling, benumbing sensation, lasting for some minutes. It is
soluble in water and alcohol, but is soluble with difficulty in ether. It
is used externally as a local anesthetic, especially on the mucous mem-
branes, and also internally.

Owing to its stimulant and exhilarant properties, cocaine is some-
times employed as a stimulant, and occasionally cases of the cocaine
habit are met with, which is more demoralizing than the morphine
habit.

Colchicine, $C_{21}H_{22}(CH_3O)NO_5$, occurs in *Colchicum autumnale*
and in other plants of the same family. It is a yellow-white, gummy,
amorphous substance (usually amorphous), with a melting point of
about 147° C. (296° F.). It is readily soluble in water, alcohol,
and chloroform. It is employed, like the plant, in the treatment of

rheumatism and gout, in doses of from $\frac{1}{120}$ to $\frac{1}{20}$ of a grain. By the process of hydrolysis, this alkaloid yields a second one, called **colchiceine**, $C_{21}H_{22}OHNO_5$. This substance is readily soluble in boiling water, alcohol, and chloroform, and but slightly soluble in cold water. It is occasionally employed in medicine.

Hyoscyamine, $C_{17}H_{23}NO_3$, is an alkaloid occurring in belladonna and hyoscyamus. It is isomeric with atropine, and is easily converted into it. It occurs as yellow-white, amorphous, resinous-like masses, or as prismatic crystals, having, particularly when damp, a tobacco-like odor, and an acrid, nauseous, bitter taste. It is deliquescent on exposure to the air. It is very soluble in water and alcohol, and almost insoluble in ether. It dilates the pupils, like atropine, and possesses sedative properties.

Hyoscyaminæ sulphas, $(C_{17}H_{23}NO_3)_2H_2SO_4$, and **hyoscyaminæ hydrobromas**, $C_{17}H_{23}NO_3HBr$, are official in the U. S. P.

Hyoscine, $C_{17}H_{21}NO_4$, is another alkaloid obtained from hyoscyamus. **Hyoscine hydrobromate** is official. It occurs in colorless, transparent, rhombic crystals, soluble in water and alcohol. Its solution has a bitter, slightly pungent taste. It is employed as a sedative and hypnotic, and is especially used in mania and in neuralgias. It is more active and rapid in its effects than either atropia or hyoscyamine.

Opium and Its Alkaloids.—Opium is the concrete, milky exudation of the unripe capsules of the *Papaver somniferum*, or poppy. It is, chemically, a mixture of a large number of substances, containing gum, albumin, wax, volatile and coloring matters, meconic acid, meconin, and no less than sixteen or eighteen alkaloids, the most important of which are morphine and codeine.

The value of opium in commerce is generally determined by an assay for the quantity of morphine present in it. Ordinary opium should not contain less than nine per cent. of morphine, and when dried at $85°$ C. ($185°$ F.) it should contain from twelve to sixteen per cent. of this alkaloid, when estimated according to the method of the U. S. P.

Opium occurs in the market in irregular or globular masses, with remnants of poppy-leaves adhering to the surface. It is usually plastic in consistency, of a dark brown color, and a somewhat shining appearance ; it has a nauseous, peculiar, bitter taste. When the gum is dried, powdered, and exhausted with ten times its own weight of strong ether, the ethereal solution separated, and sugar of milk added to restore the original weight, it forms the denarcotized opium of the U. S. P. The principal alkaloid of opium is morphine.

Morphine, morphina (U. S. P.), $C_{17}H_{19}NO_3.H_2O$, occurs in short, transparent, trimetric prisms, odorless, very bitter, and fusing at

120° C. (248° F.). Morphine is soluble in hot water, alcohol, and amyl-alcohol, but nearly insoluble in cold water, and only slightly soluble in cold alcohol and amyl-alcohol. It gives a blue color with neutral solutions of Fe_2Cl_6; it decomposes iodic acid, giving free iodine. Its solutions are levorotatory. It is especially noted for its anodyne properties.

Morphine dissolves readily in dilute acids, forming very soluble and crystallizable salts, the most important of which are **morphinæ acetas** (U. S. P., Br.), **morphinæ hydrochloras** (U. S. P., Br.), and **morphinæ sulphas** (U. S. P., Br.). When heated with large excess of HCl, morphine gives **apomorphine**, $C_{17}H_{17}NO_2$, which is precipitated as a white powder by sodium carbonate, and turns green on exposure to the air. It is said to be formed spontaneously in old morphine solutions. The hydrochlorate is a speedy, non-irritant emetic.

Physostigmine, eserine, physostigma, $C_{15}H_{21}N_3O_2$, is an alkaloid obtained from the Calabar bean, *Physostigma venenosum*. It is a crystalline or amorphous, brown-yellow powder. Its solutions vary in color from red to blue, and are strongly alkaline in reaction. It is a violent poison, and strongly contracts the pupils. The salicylate, occurring in crystalline prisms, and the sulphate, a yellow-white, crystalline powder, are official.

Piperine, $C_{17}H_{19}NO_3$, is the alkaloid of pepper. It crystallizes in colorless, tasteless, odorless prisms, melting at 130° C. (266° F.). The alcoholic solution has a sharp, peppery taste and a neutral reaction. It is soluble in alcohol, but almost insoluble in water.

Pilocarpine, $C_{11}H_{16}N_2O_2$, is the principal alkaloid of jaborandi. It is uncrystallizable, but its salts crystallize from alcohol. With H_2SO_4 it forms a colorless solution. The nitrate and hydrochlorate are much used in medicine. Given internally, they produce rapid and profuse diaphoresis and salivation, quickened pulse, and lowered temperature. With large doses the heart stops in diastole. The hydrochlorate, **pilocarpinæ hydrochloras** (U. S. P.), is official. It occurs as small, white, odorless crystals, having a slightly bitter taste, very soluble in water or alcohol. It is deliquescent.

Strychnine, strychnina (U. S. P., Br.), $C_{21}H_{22}N_2O_2$, exists in the seeds and bark of *nux vomica*, and in the seeds of *Strychnos ignatia*, "St. Ignatius' bean," and other plants of the same family. It crystallizes in white, fusible, four-sided, trimetric prisms. Its bitter taste can be detected in a solution containing one part in one million parts of water. It forms soluble crystalline salts, and is a violent poison, producing tetanic convulsions. The physiological antidotes are morphine, atropine, and chloral hydrate. A delicate **test** is to dissolve the suspected substance in sulphuric acid and add a fragment of

potassium dichromate, when a deep purple-red color is produced if strychnine is present.

The British Pharmacopœia does not recognize any of the salts of strychnine. In Germany the nitrate is official, and in the U. S. P. the sulphate, which is used largely in medicine. The phosphate and nitrate are also used in this country.

Theobromine, $C_7H_8N_4O_2$, occurs in the seed or bean of *Theobroma cacao.* It closely resembles caffeine in its physiological action. It is eliminated by the kidneys, and can be detected in the urine. It forms small, white, trimetric crystals, sparingly soluble in water, alcohol, and ether. It has a slightly bitter taste. The salicylate of theobromine and sodium is used under the name of **duretin.** Its salts are unstable and decompose in contact with water.

Veratrine, veratrina (U. S. P., Br.). occurs in *Asagræa officinalis.* The commercial substance is a mixture of three alkaloids—cevadine, veratrine, and cevadilline. White prisms or powder, melting at $175°$ C. ($347°$ F.) and solidifying, on cooling, to a resinous mass. Its dust causes violent sneezing ; it is a violent poison. Concentrated H_2SO_4 forms a yellow solution, which gradually becomes red. These alkaloids all form crystalline salts. The oleate and an ointment of veratrine are official.

PTOMAINES.

Putrefactive or Cadaveric Alkaloids.—These alkaloids are produced during the putrid decomposition of animal and vegetable matter, and probably in certain pathological conditions in the human body during life. They are the result of the growth of the bacteria that produce the decomposition of dead animal and vegetable tissues.

Some of these bases are very poisonous, producing symptoms resembling those caused by strychnine, atropine, coniine, etc. Selmi obtained poisonous bases containing arsenic from the body of a subject who had died of arsenical poisoning and was exhumed fourteen days after death. It is probable that the symptoms of poisoning by preserved foods, such as canned fish, meat, etc., that are occasionally seen, are due to the presence of some one of these alkaloids. Tainted meat, fish, etc., should not be eaten. The author has known of a number of cases of poisoning from this cause.

Some of these alkaloids decompose with great ease. giving a cadaveric odor, while others remain permanent. Although they are most likely to be found in putrefying animal matters, they have been produced by the putrefaction of maize, leguminous substances, flour, etc. Many of the ptomaines are volatile and amorphous, but form

crystalline salts with the acids. They answer to nearly all the ordinary reactions of the vegetable alkaloids. They seem to possess less stability, and generally have a greater tendency to undergo oxidation, than the vegetable bases, and hence frequently act as reducing agents. The ptomaines are formed during the earlier stages of the putrefactive processes, and as putrefaction progresses they gradually disappear, and give place to well-known aromatic or benzenoid compounds. Brieger found that there are produced at first oxygenated bases, like cholin, muscarin, neurin, gadinin, and tetanin.

These seem to disappear afterward, and amins take their places, such as dimethylamin, trimethylamin, triethylamin, putrescin, cadavarin, saprin, neuridin, collidin, hydrocollidin, parvolin, and tyrotoxicon (diazobenzene). Some of these are volatile and others decompose on the application of heat, especially on evaporation to dryness.

The number of these alkaloids that have been isolated is considerable. Some of them have not been sufficiently studied to determine their constitution. Some of these bases so closely resemble the vegetable alkaloids that they have been mistaken by chemists for the latter. The alkaloids likely to be confounded with ptomaines are coniine, nicotine, strychnine, morphine, atropine, digitaline, veratrine, delphinine, and colchicine. Not only do the ptomaines have many reactions that have been heretofore regarded as characteristic of the above-named alkaloids, but their presence in some cases prevents the detection of certain alkaloids by the usual reagents. These facts have a very important bearing upon the toxicological search for the alkaloids. Indeed, serious mistakes have been made by chemists who have had charge of such analyses, owing to imperfect knowledge of these putrefactive alkaloids.

The separation of the ptomaines from the vegetable alkaloids is attended with great difficulty. Tamba states that the oxalates of the vegetable alkaloids are precipitated from solutions of mixtures in ether, while the oxalates of the ptomaines are soluble. That is, if to an ethereal solution of the alkaloids an equal volume of a saturated solution of oxalic acid in ether be added, the oxalates of the vegetable alkaloids separate out on standing, while the ptomaines remain in solution. Cadaverin is said to precipitate along with the vegetable alkaloids. Another somewhat distinctive reaction for the ptomaines is their reducing action upon potassium ferricyanide. If a solution containing ferric chloride and potassium ferricyanide be treated with a drop or two of a solution containing a ptomaine, the ferricyanide is reduced to ferrocyanide, which gives an immediate precipitate of Prussian blue with the ferric chloride. The only vegetable alkaloids thus far known to reduce ferricyanides are morphine and veratrine.

Physiological Action of Ptomaines.—The cadaveric alkaloids are not all toxic. Of those which are, there is a great variation in the degree, as well as in the symptoms produced. The free ptomaines are more energetic than their salts. The principal symptoms observed in dogs are the following : (1) Dilatation of the pupil, followed by contraction, sometimes irregular contraction, of the pupils ; (2) paralysis of the vasomotor nerves, causing an increased cutaneous heat and injection of the helices of the ears ; (3) cessation of, or slowing of the respiration ; (4) somnolence, followed by convulsions and death ; (5) loss of muscular contractility to electrical stimulus. Very little seems to be known of the effects of individual ptomaines upon man. What has often been called ptomaine poisoning is the result of a mixture of substances in which we have no evidence that ptomaines exist, or that they are the cause of the symptoms if present. Such poisoning is more properly called "**food-poisoning.**" The poison of meat or sausage is called **botulismus toxin,** and is not, as formerly supposed, a ptomaine. As our knowledge of food-poisoning increases, it becomes more probable that ptomaines play little part in producing the symptoms, but that they are due to **toxins,** or to a mixture of causes.

Food-poison and botulismus will be treated of under Toxins.

The term toxin is applied to a poison produced by bacterial action, without definite knowledge as to whether it be a ptomaine or a poisonous proteid. Among the non-poisonous ptomaines are a number of the amin bases which may be formed by other processes than putrefaction. Among these may be mentioned methylamin, dimethylamin, trimethylamin, ethylamin, diethylamin, triethylamin, propylamin, and neurodin, most of which have been mentioned among the amins. We may mention in addition, mydin, $C_8H_{11}NO$; pyocyanin, $C_{14}H_{14}NO_2$, and betaïn, $C_5H_{11}NO_3$.

The most important of the poisonous ptomaines are the following :

Cadaverin, $C_5H_{14}N_2$, occurs very frequently in decomposing animal tissue. It is not very poisonous, but is capable of producing intense inflammation and suppuration, even in the absence of bacteria. It appears late in the putrefactive process, but readily in cultivations of the cholera bacillus and the Finckler-Prior vibrio. It belongs to the diamins, and is chemically pentamethylenediamin. It is a syrupy liquid, possessing an unpleasant odor resembling that of coniine.

Cholin, $C_5H_{15}NO_2$, is similar in properties to neurin, and has been already mentioned among the organic bases.

Muscarin, $C_5H_{13}NO_2$, was first discovered in poisonous mushrooms, *Agaricus muscarius*. It has also been obtained by the oxidizing action of HNO_3 on cholin. It is closely related, therefore, to this base. It has been obtained also from putrid fish. It is a very active poison,

acting upon the muscular tissue itself, especially that of the heart. It is antagonistic to atropine in its action upon the heart. Atropine may, therefore, be regarded as its physiological antidote.

Neurin, $C_5H_{13}NO$, is a syrupy base of strong alkaline reaction, and has been obtained synthetically by boiling protagon from brain-substance with baryta, and by other synthetic processes. It is a constant product of cadaveric putrefaction, and is a more powerful toxic agent than cholin, with which it is usually associated. Atropine is its physiological antagonist, and its poisonous symptoms may frequently be dispelled by a hypodermic injection of a small dose of this alkaloid.

Cholin, muscarin, and neurin usually occur together. They are all active poisons—cholin and neurin acting like curara, muscarin acting on the muscular tissue itself. They are all antagonized by atropine, so far as relates to their action on the heart. They are usually present in the putrefaction of proteids, and are sometimes concerned in producing the symptoms seen in cases of poisoning by putrid foods.

Gadinin, $C_7H_{17}NO_2$, has been obtained from putrefying codfish.

Mytilotoxin, $C_6H_{15}NO_2$, is the active agent in poisonous mussels.

Typhotoxin, $C_7H_{17}NO_2$, is an alkaloid which has been obtained from pure cultures of the bacillus of typhoid fever, and is supposed to be the chemical poison concerned in producing the symptoms in this disease.

Typhotoxin, when injected into the circulation of animals, produces a lethargic or paralytic condition, in which the animal falls down helpless. Frequently diarrheal evacuations take place, and death follows in from one to two days.

Tetanin, $C_{13}H_{30}N_2O_4$, is supposed to be the chemical poison in cases of tetanus. There is also a toxin of tetanus, and an antitoxin.

Tyrotoxicon, $C_6H_5N_2$, is a poison which has been separated from poisonous cheese, ice-cream, and milk. Its true chemical composition has not yet been established. It is supposed to be the active agent in producing the symptoms usually seen in cases of cheese poisoning.

Putrescin, $C_4H_{12}N_2$ (**tetramethylenediamin**), is usually found accompanying cadaverin, but makes its appearance much later. It is found, together with cadaverin, in feces and urine. It is a poison, but not very virulent.

The symptoms produced by it are very similar to those of cholera, but the muscular cramps and other symptoms produced in cholera are probably caused by other poisonous substances.

TOXINS.

Poisonous Proteids and Allied Poisons.—Protein substances readily undergo decomposition under the influence of the growth of various micro-organisms.   Some of these decomposition products, when introduced into the circulation, are poisonous.   The poisonous proteids are not easily distinguishable, by chemical or physical proper-ties, from non-poisonous or food proteids.   The most important of the vegetable proteid poisons are those contained in the seeds of *jequirity*, **ricin,** from castor-oil beans, that associated with papain, and that from *Lupinus luteus*.

The most important of the animal poisons are snake-poison, the proteids in the serum of the conger-eel, that found in certain spiders, and, under certain conditions, albumoses and peptones.   In the case of snake-poison no bacteria seem to be present, and the proteids, separated in the pure condition, are as poisonous as the original venom.   The venom of the cobra and viper, according to the most recent analyses, are found to contain globulin, albumin, and syntonin in the former, and globulin, albumin, and albumoses in the latter, all of which are poisonous.   The chief symptom produced is asphyxia. The venom of the cobra has about the same toxicity as the toxin of diphtheria.   One four-millionth of the body-weight will produce death.   The disease-producing bacteria form, as a result of their growth, certain substances which are more or less poisonous.   Pure cultures of the anthrax bacillus produce a substance which, if inocu-lated into animals, renders them immune from anthrax.   This prin-ciple is believed to explain the cause of immunity in animals who have suffered from certain specific diseases.   The immunity of animals who have suffered from a contagious disease is supposed to be due to the production of these products of the growth of the specific micro-organ-ism of that disease, and immunity may be produced by injecting these products.   Most specific organisms produce a toxin, or poison, and an antitoxin, or protective principle.   It does not, however, appear that in all cases two substances are necessarily formed.   The bacillus of diphtheria has been shown to produce a proteid which, when injected into animals, produces diphtheritic symptoms.   These proteids obtained from bacterial growth have been named toxins. They appear, however, to be an active form of albumose or peptones, rather than albumin.   Other poisonous proteids have been obtained from cultures of the bacilli of tetanus, cholera, and typhoid fever. The proteids found in the latter case are usually highly poisonous when injected under the skin of dogs or other lower animals, produc-

ing vomiting, purging, collapse, and death. Koch's **tuberculin** is the impure toxalbumin, or albumose, resulting from the growth of the tubercular bacillus in pure cultures.

Tuberculocidin is the purified albumose which is used in the treatment of tuberculosis. The amount employed is said to be about ⅓ of a grain per day.

Diphtheria antitoxin is a clear, transparent serum obtained from the blood of an animal, usually the horse, which has been rendered immune by repeated injections of a pure culture of the diphtheria bacillus rendered sterile by filtration and the addition of some antiseptic. It is supposed to contain the protective principle against the toxin of diphtheria, which has been developed by the horse during the immunizing process.

Protective serums have been prepared for cholera, tetanus, rabies, anthrax, and other diseases. Our knowledge of the chemical composition of toxins and antitoxins is not yet very definite.

Botulismus Toxin, or Meat-poison.—This is a toxin discovered by Van Ermengem, in 1896. He discovered a specific anaërobic bacillus in a ham that had poisoned a number of people, which produced a toxin in pure cultures, which produced in animals the characteristic symptoms of meat poisoning, technically known as **botulismus** (from *botulus*, a sausage).

Kempner prepared an antitoxin in animal experiments, showing the analogy between this toxin and that of the specific diseases. The symptoms of botulismus are increase of salivary secretion, dilatation of the pupil, strabismus, and disturbances of speech, retention of urine, but no fever or brain symptoms.

Several observers have noted certain degenerative changes in the nerve-cells of the spinal cord in animals. Other poisons probably occur in the various meats, and in other foods producing poisoning.

Until recently, food poisoning—*i. e.*, cheese poisoning, ice-cream poisoning, sausage poisoning, fish poisoning, clam and oyster poisoning, etc,—was believed to be due to alkaloidal substances classed as ptomaines. The above mentioned discovery seems to indicate that many, at least, of such poisons are poisonous proteids instead of alkaloids, closely allied to the toxins of diphtheria, tetanus, and other contagious diseases.

Until more is known of these poisons we must look upon cases of such poisoning as simply **food poisoning.**

The **symptoms of food poisoning** in man, although varied by the character of the poison and the condition of the individual at the time, are generally those of a powerful gastro-intestinal irritant. There is usually a period of incubation of from two to six hours.

With a given article of food undergoing putrid fermentation, there is frequently a remarkable agreement in this period of incubation in different persons, the symptoms in all beginning within a few minutes of the same time. There is usually sudden and severe retching, with abdominal pain, prostration, disturbed circulation, and often delirium. There is sometimes dilatation of the pupils and redness of the skin, or a fine, scarlatina-like eruption. Thirst is usually intense. Diarrhea is frequent, but not always present; the discharges are very offensive. Muscular twitchings, and even convulsions, may be met with. There is a tendency to collapse, which must be guarded against. The temperature is in some cases elevated, and in others it is below normal.

The above description applies to the symptoms usually met with in cases of poisoning by food in a state of beginning decomposition.

LEUCOMAINES.

This term is applied by Gautier to those alkaloidal or basic substances elaborated in the body during life. They are either the result of fermentative changes within the body, or of the natural physiological processes in the cells, or by retrograde changes in the nitrogenous tissues. Most of these alkaloids are deleterious to the subject when anything interferes with their oxidation or elimination. They are eliminated, in part at least, by the kidneys. They act especially upon the nerve-centers, producing sleepiness, lassitude, or occasionally vomiting and purgation. Some of them produce a febrile condition, while others produce a lowered temperature. Some of them are to be found in the excreta—viz., in the urine, feces, perspiration, etc. Some are to be found principally in the muscles, saliva, brain, liver, spleen, and other glandular bodies. The quantity and character of the leucomaines vary with pathological conditions. The urinary leucomaines have received special study. Though scarcely to be found in certain normal urines, they are greatly increased in certain diseases, so that this fluid may at times become very poisonous when introduced into the circulation.

Without giving a detailed description of these bodies, we give the following list of names, formulæ, and sources of the principal leucomaines:

The Xanthin Group of Leucomaines.—These are all closely related to uric acid, as will be seen by comparison of the formulæ. Most of them have already been described in a former chapter.

(Uric acid, $C_5H_4N_4O_3$).
Adenin, $C_5H_5N_5$, pancreas, spleen, kidneys, lymphatic glands.

Hypoxanthin, $C_5H_4N_4O$, spleen, muscles, urine, kidney, etc.
Guanin, $C_5H_5N_5O$, guano, liver, pancreas, lungs.
Xanthin, $C_5H_4N_4O_2$, urinary calculus, almost all tissues.
Heteroxanthin, $C_6H_6N_4O_2$, urine of man and dog.
Paraxanthin, $C_7H_8N_4O_2$, urine of man.
Carnin, $C_7H_8N_4O_3$, extract of meat.
Pseudoxanthin, $C_4H_5N_4O$, beef-muscle.
Spermin, C_2H_5N, spermatic fluid, sputa of bronchitis, spleen.

The Creatinin Group of Leucomaines.—

Creatinin, $C_4H_7N_3O$, urine.
Creatin, $C_4H_9N_3O_2$, urine.
Xanthocreatinin, $C_5H_{10}N_4O$, muscle.
Crusocreatinin, $C_5H_8N_4O$, muscle.
Amphicreatinin, $C_9H_{19}N_7O_4$, muscle.

Some of these bodies are said to be poisonous, and it is suspected that uremia and many of the nervous symptoms of dyspepsia are due to their action. There are probably many more of these substances than have been isolated. It is known that there are certain poisonous substances destroyed in the liver. There are certain poisons thrown out with the breath, the urine in certain diseases, the saliva of man and other animals, and in various other tissues and fluids. Much remains to be learned of these substances.

THE GLUCOSIDES.

The **glucosides** are a class of compounds widely distributed throughout the vegetable kingdom. They may be resolved into a sugar and another compound by acids, alkalies, or certain ferments. They are probably ethers of dextrose, or a related sugar. They show a wide range of properties and composition. Solanin, for example, is a base, while others have a distinct acid reaction. They are usually soluble in water and alcohol. Most, but not all of them, reduce Fehling's solution. They are not decomposed, as a rule, by water, but are easily decomposed by heating with dilute H_2SO_4 or HCl. Many of them are optically active. A few of them occur in the animal body. Many of them are used in medicine. We can mention here but a few of the more important of these bodies.

Amygdalin, $C_{20}H_{27}NO_{11}$, occurs in bitter almonds, in the kernels of cherries, plums, and apricots, and in the leaves of the laurel. Extracted from almonds by boiling alcohol, and precipitated by adding ether, it is obtained as pearly scales. When **emulsin** (the ferment of bitter almonds) is added, it splits up into hydrocyanic acid, HCN, benzaldehyde, C_6H_5COH, and dextrose.

Arbutin, $C_{12}H_{16}O_7$, is extracted from the leaves of *Uva ursi*. It is soluble in water, has a bitter taste, and is crystalline. Emulsin and diluted acids split it into dextrose and hydroquinone.

Antiarin, $C_{14}H_{20}O_5 . 2H_2O$, is the active principle of the arrow poison of Java; crystalline, soluble in water and alcohol. It is obtained from the milky juice of *Antiaris toxicaria*.

Coniferin, $C_{16}H_{22}O_8 . 2H_2O$, occurs in the cambium sap of the *coniferæ*, and crystallizes in stellate groups of prisms. Emulsion yields dextrose and coniferyl alcohol. This latter, when treated with sulphuric acid and potassium dichromate, yields artificial **vanillin,** a body identical with that obtained from the vanilla bean. It is now manufactured on a large scale.

Convolvulin, $C_{31}H_{50}O_{16}$, is the active principle of jalap—a resinous mass, soluble in alcohol and alkalies. **Jalapin,** $C_{34}H_{56}O_{16}$, exists with the above in jalap.

Digitalin is a poisonous substance existing in common fox-glove ; it forms an amorphous powder having an intensely bitter taste.

It is readily soluble in water and absolute alcohol. Three glucoside principles have been described as occurring in digitalis—**digitalein, digitonin, digitalin.** Digitalein, whose formula is $C_5H_8O_2$, occurs as a yellowish, amorphous powder, freely soluble in water and alcohol. It is said to combine the properties of digitalin and digitoxin. Digitoxin, $C_{21}H_{33}O_7$, is a white, crystalline body of a bitter taste, readily soluble in chloroform, but insoluble in water. When subjected to hydrolysis it does not yield sugar, but other products. It is used in medicine.

Esculin, $C_{15}H_{16}O_9$, and **esculetin,** $C_9H_{16}O_4$, occur in the bark of the horse-chestnut tree ; sparingly soluble in cold, more freely in hot water ; are crystalline and have a bitter taste.

Fraxin, $C_{32}H_{36}O_2$, is found in the bark of the ash and horse-chestnut trees, and forms colorless, needle-like crystals, soluble in water, furnishing a bitter, fluorescent solution.

Glycyrrhizin, or **licorice-sugar,** $C_{24}H_{36}O_9$, is the sweet principle of licorice. It is a yellow, amorphous powder, having a sweet, acrid taste. It is soluble in water and alcohol. Acids split it into a sugar and **glycyrrhetin.**

Helleborin, $C_{36}H_{42}O_6$, is found, together with **helleborein,** $C_{26}H_{44}O_{15}$, in the root of green hellebore. It is insoluble in water, and forms glistening needles. It is a powerful poison.

Indican, $C_{52}H_{62}N_2O_{34}$, occurs in all plants yielding indigo. It is a pale brown, syrupy liquid, having a bitter taste. When allowed to ferment, or when treated with diluted acids, it forms indigo-blue and indiglucin, a form of sugar. Indigo has been prepared synthetically from cinnamic acid, which may be prepared from toluene. A substance called indican is found in the urine, but this is not identical with plant-indican.

Picrotoxin, $C_{30}H_{34}O_{13}$, colorless, lustrous, bitter needles, obtained from the fruit of *Anamirta paniculata*. It reduces alkaline copper solutions. It has an intensely bitter taste, and is soluble in alcohol and in water. It is employed in medicine, and is official.

Populin, $C_{20}H_{22}O_8$, occurs with salicin, in the bark and leaves of the aspen. It forms small prisms having a sweet taste. Boiled with barium hydroxide, it yields salicin and benzoic acid.

Phlorizin, $C_{21}H_{24}O_{10} + 2H_2O$, occurs in the root-bark of the apple, plum, pear, and cherry trees, and is soluble in alcohol. It is soluble in hot water, from which it crystallizes in silky needles having a bitter taste. Boiled with diluted acids, it yields glucose and **phloretin.**

Polychroite, $C_{48}H_{60}O_{18}$, is the coloring matter of saffron, and forms an amorphous, deliquescent, ruby-red mass.

Quercitrin, $C_{36}H_{38}O_{20}$, or **flavin,** $C_{27}H_{28}O_{12}$, occurs in tea, quercitron, sumach, grape-wine, catechu, etc. It is slightly soluble in water, soluble in alcohol, and forms small, yellow crystals, which may be partially sublimed in beautiful yellow needles. It is colored green by Fe_2Cl_6.

Salicin has already been described under salicylic acid, *q. v.*

Santonin, santoninum (U. S. P.), $C_{15}H_{18}O_3$, is a glucoside with acid properties obtained from various species of *Artemisia*. It crystallizes in colorless, tasteless, odorless, rectangular prisms, which turn yellow on exposure to the light. It is sparingly soluble in hot water, alcohol, and ether, and insoluble in cold water. Patients taking santonin excrete the coloring matter by the urine, which assumes a yellow color, which, on treatment with an alkali, changes to cherry-red or crimson. This color is discharged by an acid. The coloring matter is also deposited in various other tissues, and when a patient is taking large doses objects appear green from the staining of the tissue of the eye.

Saponin, $C_{32}H_{54}O_{18}$, occurs in *quillaia*, or soap-tree bark, and other plants. It is soluble in water and alcohol. Its solution behaves like soap solutions. It is poisonous, but it is sometimes added to soda-water to produce a permanent froth. Its dust causes sneezing.

Solanin, $C_{42}H_{67}NO_{16}$, occurs in sprouted potatoes. It is a glucoside; soluble in alcohol, nearly insoluble in water, and forms gum-like salts.

Strophanthin, $C_{20}H_{24}O_{10}$, is a glucoside obtained from strophanthus, in the form of white, bitter, crystalline plates; slightly soluble in water, soluble in alcohol, and insoluble in ether, carbon disulphide, or benzene.

The **tannins** form a group of bodies found widely distributed in

plants. They are soluble in water, have an acid reaction, an astringent, bitter taste, and form an insoluble compound with gelatin and albumin. They unite with animal skin, forming leather. With ferric salts they form blue-black or green precipitates. They are used in the preparation of inks, in dyeing, and in tanning.

Gallotannic acid, acidum tannicum (U. S. P., Br.), $C_{14}H_9O_9H$, occurs in oak-bark, nut-galls, sumach, and some other plants, in considerable quantities. It may be extracted with a mixture of ether and alcohol. It is an amorphous, shining mass. Ferric salts give with it a bluish-black precipitate (ink); tartar emetic, a white one. It precipitates starch, gelatin, albumin, and most alkaloids. Its watery solution decomposes when exposed to the air for some time, yielding gallic and ellagic acids. Diluted mineral acids, when boiled with it, give gallic acid and dextrose.

Quinic or **quinotannic acid**, $C_7H_{12}O_6$, occurs chiefly in cinchona-barks as a salt of quinine, but is also found in the bilberry and coffee-bean. It occurs as oblique, rhombic prisms. It is soluble in water. On dry distillation it yields, among other products, benzoic acid and phenol.

Other tannic acids are known, as **caffeetanic,** of coffee; **quercitannic,** of oak; **catechutannic,** of catechu; **kinotannic,** of kino. etc., which vary slightly in properties, according to their sources.

PROTEIDS.

ALBUMINOUS COMPOUNDS.

This important class of bodies forms the chief part of the solid constituents of blood, muscle, lymph, glands, and other organs of animals, and is also found in plants, principally in the seeds. They are the principal substances taking part in the physiological changes in the organism, and constitute the physical basis of life. They are mostly colloid (not crystalline), do not readily diffuse through animal membranes, and are very prone to decomposition. They all contain carbon, hydrogen, nitrogen, and oxygen, while most of them contain sulphur in addition, and all contain some ash, mostly in the form of calcium phosphate. Independent of the ash, they have about the following composition:

Carbon, ...	50 to 54	per cent.
Hydrogen, ...	6.7 to 7.6	"
Nitrogen, ...	13 to 18	"
Oxygen, ...	21 to 26	"
Sulphur, ...	0.4 to 1.6	"

GENERAL PROPERTIES OF THE PROTEIDS.

Solubility.—All proteids are insoluble in alcohol, some are soluble in water, others insoluble. Some of those insoluble in water are soluble in weak saline solutions. Some are insoluble in concentrated saline solutions, while others are soluble. All proteids are soluble with the aid of heat, in concentrated mineral acids, caustic alkalies, and acetic acid. Most of them are soluble in the gastric and pancreatic juices, but they undergo chemical change during solution.

Heat Coagulation.—Many of the proteids which are soluble in water or NaCl solutions are rendered insoluble when these solutions are heated to near the boiling point. This precipitation is termed **coagulation.** The temperature at which the proteids coagulate is fairly constant for the same substance, and, as different proteids coagulate at different temperatures, this method may be employed for the separation of mixtures of different proteids. Unless in very concentrated solutions, they are not coagulated by heat in alkaline solutions, but are converted into alkali-albumin. Acid-albumin does not form so readily as alkali-albumin, and hence slightly acidulated albumin solutions coagulate readily when heated. An excess of acid, however, dissolves the precipitate, thus forming an acid-albumin. The temperature of coagulation of the different proteids varies between 73° and 84° C. (163.4° and 183.2° F.) for albumins, and between 56° and 75° C. (132.8° and 167° F.) for globulins.

All proteids which are coagulated by heating their solutions come under two classes—the **albumins,** which are soluble in water and weak saline solutions, and the **globulins,** which are insoluble in water and soluble in weak saline solutions. All the proteids are levorotatory. If pure and in solution, they may be detected and estimated by their specific rotatory power. The specific rotatory power of serum-albumin is —56 ; egg-albumin, —35 ; serum-globulin, —59.7.

GENERAL REACTIONS OF PROTEIDS.

First. Heated with strong HNO_3, they and their solutions turn yellow, and deepen into an orange color on adding NH_4OH, NaOH, or KOH (Xanthoproteic reaction.) If proteids be present, except albumoses and peptones, a white or yellow precipitate is always obtained on adding the acid.

Second. **Millon's reagent** is prepared as follows : One part by weight of mercury and two of strong HNO_3 are mixed and gently warmed until the mercury is dissolved. The solution is diluted with twice its volume of water, and the precipitate allowed to settle. The clear supernatant fluid is Millon's reagent. If a few drops of this solution be added to a solution of the proteids, a white precipitate occurs, which, on heating, becomes brick-red in color. If they are present only in traces, no precipitate is obtained, but the solution is colored red.

BEHAVIOR OF THE PRINCIPAL PROTEIDS WITH PRECIPITANTS.

Name of Proteid.	Solubility in Water (Cold or Warm).	Temperature of Coagulation.	Weak Solution of NaCl (1 to 5%).	Saturated Solution of NaCl or MgSO₄.	Saturation with (NH₄)₂SO₄.	Acetic Acid with Potass. Ferrocyanide.	Pure HNO₃ (Cold).	Absolute Alcohol or Tannin with NaCl.	Acetic Acid with (1) Picric Acid; (2) Sodium Tung-state; or (3) Potass. State; Mercuric Iodide.	Sodium Hydroxide with Copper Sulphate.	Copper Sulphate.
Serum-albumin, Egg-albumin, Cell-albumin, Muscle-albumin, Lactalbumin,	s. s. s. s. s.	73° 73° 73° 73° 77°C.	s. s. s. s. s.	Not pptd. " " " "	Pptd. " " " "	Pptd. " " " "	Pptd. " " " "	Pptd. " " " "	Pptd. " " " "	Violet. " " " "	. . . . .
Serum-globulin, Fibrinogen, Myosinogen, Globin, Myoglobulin, Vitellin, Crystallin,	Ins. " " " " " "	7° 30° 56° 63° 75° 73°	Pptd. on boil-ing. s. s. s. s. s. s.	Pptd. " " " Not pptd.	Pptd. " " " " " "	Pptd. " " " " " "	Easily soluble in weak acids and alkalies. s. s. s. s. s. s.	Pptd. " " " " " "	Pptd. " " " " " "	Violet. " " " " " "	. . . .
Acid-albumin,	Ins.	Not at 100°C.	Ins.	Pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Pptd.	Violet.	.
Syntonin, Alkali-albumin, Caseinogen,	S. Ins. " "	Partly pptd. at 65° with NaCl Not at 100°.	S. S.	Pptd. " "	Pptd. " "	Pptd. " "	Not pptd. " "	Pptd. " "	Pptd. " "	Rose-red. " "	Pptd. " "
Proto-albumose, Hetero-albumose,	S. Ins.	Not at 100°C. " "	S. S.	Pptd. Soluble when hot.	Pptd. " "	Pptd. " "	Not pptd. " "	Pptd. " "	Pptd. " "	Rose-red. "	Pptd. "
Dutero-albumose,	S.	Partly pptd. at 65° with NaCl Not at 100°.	S.	Not pptd. Soluble when hot.	Not pptd.	Not pptd.	Not pptd.	Pptd.	Pptd.	"	Not pptd.
Peptone,	S.	. . .	S.	Not pptd.	Not pptd.	Not pptd.	Not pptd.	Pptd.	Pptd. sol. on heating.	Rose-red.	Not pptd.

Third. **Adamkiewicz's reaction.** Add an excess of glacial acetic acid, and then concentrated H_2SO_4. A violet color with a feeble fluorescence is formed if proteids are present. This reaction is not delicate.

Fourth. **Liebermann's reaction.** If albumin is precipitated with alcohol and washed with ether, it gives a deep violet color when heated with HCl.

Fifth. **Piotrowski's reaction.** If mixed with an excess of a strong solution of NaOH, and one or two drops of a diluted solution of $CuSO_4$ be added, a violet color is obtained, which deepens in tint on boiling. This is also termed the **biuret reaction.** In the case of albumoses and peptones, the color is rose-red with KOH and reddish-violet with NH_4OH.

The above tests serve to detect traces of proteids, and depend upon the development of colors. The following reactions depend upon the precipitation of the proteid from its solution.

Sixth. Make the fluid strongly acid with acetic acid and add a few drops of a solution of $K_4Fe(CN)_6$. A precipitate shows the presence of proteids, except peptones and some forms of albumose.

Seventh. Render the fluid strongly acid with acetic acid, and add an equal volume of a concentrated solution of Na_2SO_4, and boil. This precipitates all proteids except peptones. This test is useful because it effects a very complete separation of proteids, except peptones, and the reagent employed does not interfere with other tests which are likely to be performed upon the solution, after the removal of the proteids by filtration. It is, therefore, useful to separate albumin from solutions before testing for sugar.

The following precipitate all proteids : Tannic acid in the presence of a faint excess of acetic acid ; double iodide of mercury and potassium with a slight excess of HCl (Brücke's reagent) ; phosphotungstic acid in the presence of a considerable excess of HCl; excess of absolute alcohol in neutral or faintly acid solutions. Various neutral salts, more particularly ammonium sulphate and magnesium sulphate, have been employed for the precipitation and separation of the several proteids.

CLASSIFICATION OF THE PROTEIDS.

The proteids are conveniently classified as follows :

Class 1. **Native Albumins.**—Soluble in H_2O ; solution coagulated by heating, especially with dilute acids ; not precipitated by alkaline carbonates or NaCl—e. g., egg-albumin (precipitated by ether), serum-albumin (not precipitated by ether), cell-albumin, muscle-albumin, and lactalbumin.

Class 2. **Globulins.**—Insoluble in water ; soluble in dilute NaCl solutions ; soluble in very dilute acids or alkalies ; with strong acids and alkalies rapidly changed into members of Class 3 ; readily precipitated by saturating their solutions with NaCl, $MgSO_4$, $(NH_4)_2SO_4$, and certain other neutral salts. Their solutions are precipitated by heat—e. g., (1) crystallin, of the crystalline lens ; (2) vitellin, from eggs ; (3) serum-globulin or paraglobulin ; (4) fibrinogen ; (5) myosinogen ; and (6) globin.

Class 3. **Derived Albumins, or Albuminates.**—Insoluble in distilled water and in dilute neutral saline solutions ; soluble in acids

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and alkalies ; neutral solutions not coagulated on boiling—*e. g.*, acid-albumin, or syntonin, alkali-albumin, caseinogen, anti-albumids, and glutenins.

Class 4. **Fibrins.**—Insoluble in water ; difficultly soluble in strong acids and alkalies, and undergoing a simultaneous change into members of Class 3 ; soluble by the prolonged action of a ten per cent. solution of NaCl, changing into members of Class 2.

Class 5. **Coagulated Proteids.**—These are the products of the action of heat on members of the preceding classes. or of Class 3. when precipitated by neutralization and heat. They are also obtained by the prolonged action of alcohol in excess upon Classes 1, 2, and 4.

Class 6. **Albumoses (Proteoses or Propeptones) and Peptones.**—The peptones are very soluble in water ; are not precipitated by acids, alkalies, neutral salts, or many other reagents which precipitate other proteids. They are precipitated by the prolonged action of strong alcohol, but not coagulated. They are readily diffusible.

The albuminoses are readily soluble in water, and are distinguished from the peptones by being precipitated by saturation with neutral ammonium sulphate. They yield precipitates with many of the reagents which precipitate other proteids. A characteristic feature of the albumoses is that the precipitate with HNO_3, and with $K_4Fe(Cy)_6$ in the presence of acetic acid, disappears when the solution is warmed and reappears on cooling.

Class 7. **Compound proteids** are those composed of a simple proteid united to some non-proteid body. This class includes the **mucins,** the **nucleins, nucleo-albumins,** and the compound globulins, such as **hemoglobin** and its derivatives.

Class 8. **Albuminoids,** or **gelatinoids,** are bodies that are (*a*) either soluble in boiling water, yielding gelatin ; (*b*) insoluble in boiling water, but slowly hydrated by boiling with dilute acids, and by pepsin-hydrochloric acid ; (*c*) or insoluble in boiling water, dilute acids, alkalies, and gastric or pancreatic juice.

Class 9. **Lardacein** or **amyloid substances** are insoluble in water, diluted acids, and alkalies, and are converted into albuminates by strong acids and alkalies.

ANIMAL PROTEIDS.

Serum-albumin exists in blood. chyle, lymph, and in small quantity in milk. In certain renal diseases it appears in the urine. When its neutral solutions are heated to about 73° C. (163.4° F.), it

coagulates to a flocculent precipitate, which, when dried, forms a compact, amorphous mass.

Its solutions have a specific rotatory power of —56°. Strong mineral acids first precipitate it, then dissolve the coagulum. It is not precipitated by acetic acid alone, but, when acidified with this acid, potassium ferrocyanide and ferricyanide coagulate it.

It may be obtained from blood-serum by saturating it at 36° C. (96.8° F.) with $MgSO_4$, which precipitates the globulin. The filtrate is saturated with sodium sulphate at about 40° C. (104° F.), which precipitates the serum-albumin, containing small quantities of salt. To obtain it pure, this precipitate is suspended in water and submitted to dialysis.

Pure serum-albumin is a white or pale-yellow, amorphous substance, dissolving readily in water, forming a slightly alkaline, opalescent liquid, slowly coagulating at about 73° C. (163.4° F.). It is not precipitated by ether, and with difficulty by alcohol.

The following reagents may be used to detect its presence in solution : Citric or acetic acid with potassium ferrocyanide, potassiomercuric iodide, mercuric chloride, picric acid, concentrated nitric acid, or trichloracetic acid.

Egg-albumin is found in the white of eggs, and differs from the above in being almost insoluble in nitric and hydrochloric acids, and is precipitated by alcohol and ether. Its specific rotatory power is less than that of serum-albumin, being —35.5°.

The white of egg is a semifluid substance, situated between the shell and the ovum proper, or yolk. It is permeated by a network of fibrillated matter. This network is insoluble in hot water, dilute alcohol, and acetic acid. The liquid is alkaline in reaction, and especially rich in proteids, containing about 12.2 per cent. as a mean, varying considerably in different eggs from 11 to 13 per cent. It has the following composition : Water, 82 to 88 per cent. ; solids, about 13.3 per cent. ; proteids, about 12.2 per cent. ; sugar, about 0.5 per cent. ; fats, alkaline soaps, lecithin, and cholesterin, about 0.66 per cent. (Lehman.)

The proteids of white of egg are : (1) Globulins, precipitated by dilute acetic acid, or by saturation with $MgSO_4$ or NaCl ; (2) albumins then remaining in solution.

Vegetable-albumin occurs in small quantity in most vegetable juices. It shows the same general properties as the other albumins, but contains less sulphur.

THE GLOBULINS.

The **globulins** differ from the albumins in being insoluble in water, but soluble in sodium chloride solution (1 per cent.). Except vitellin, they are precipitated by saturated solutions of the same salt. They are soluble in very dilute HCl (1 part in 1000 being sufficient), with production of acid-albumin.

Vitellin occurs in the yolk of egg. It is a white, granular body, soluble in dilute NaCl solutions, and not precipitated by a saturated solution of the same. It coagulates at about 75° C. It dissolves readily in dilute acid (0.1 per cent.) and in alkalies. It is precipitated by alcohol.

It is readily soluble in a 1 per cent. solution of Na_2CO_3, and is incompletely precipitated from its solution by dilution, but completely by passing a stream of CO_2 through it. It has not as yet been obtained free from lecithin. It may be prepared from egg-yolk by extraction with successive portions of ether as long as it yields any color to the solvent. The ether is evaporated and the residue is dissolved in the smallest possible amount of 8 to 10 per cent. NaCl solution. It is precipitated from this solution by an excess of water, and purified by the repetition of this process. The operation must be conducted as rapidly as possible, since the prolonged action of water renders the vitellin insoluble in NaCl solution. Thus obtained, it is still mixed with a small amount of lecithin.

Crystallin is usually regarded as identical with vitellin. It can be prepared in the pure form from the crystalline lens, in which it occurs to the extent of 24.6 per cent. In dilute saline solution it coagulates at 75° C.

Serum-globulin, paraglobulin, fibrinoplastin, occurs in blood, chyle, lymph, and serous fluids. In many of these fluids it exists in large quantity, and these coagulate spontaneously when removed from the living body, forming fibrin—probably by the combination of two modified forms of globulin, called fibrinogen and fibrinoplastin. Globulin is not completely precipitated by a saturated solution of NaCl, but is precipitated by alcohol, or by allowing carbon dioxide to bubble through the liquid.

Pure paraglobulin is insoluble in water. Its dilute saline solution coagulates on heating to 75° C. (167° F.). Globulins also occur pathologically in the urine, and may usually be discovered by dropping a few drops of the urine into a large quantity of distilled water, when the globulin precipitates as a white cloud.

Cell-globulin has been described as occurring in lymph-corpuscles, and may be extracted from them by NaCl solutions.

Fibrinogen.—This globulin is found in blood-plasma, together with paraglobulin and serum-albumin. It is also found in chyle, lymph, serous fluids, transudations, and hydrocele fluid. During the clotting of blood it is converted largely, if not entirely, into fibrin. It resembles paraglobulin in its general properties, but is distinguished from it by the fact that in blood-plasma, or a 1 per cent. solution of NaCl, it coagulates at 56° C. (132.8° F.), while paraglobulin coagulates at 75° C. (167° F.). It is also readily precipitated by the addition of 16 per cent. of NaCl to its solution, whereas paraglobulin is not precipitated until at least 20 per cent. is added.

It may be prepared from blood-plasma which has been prevented from coagulating by the addition of $MgSO_4$. By the addition of an equal volume of a saturated solution of NaCl, the fibrinogen is precipitated, while the paraglobulin remains in solution. The characteristic properties of fibrinogen are that in the presence of minute quantities of certain salts, of which NaCl and $CaSO_4$ are examples, the addition of fibrin-ferment causes a rich formation of fibrin. Without such addition, the solution of fibrinogen may remain permanent.

Myosin.—When an irritable contractile muscle passes into *rigor mortis*, the substance of which the muscle-fibrillæ are composed undergoes a change similar to the clotting of the blood, which results in the formation of a clot of myosin. Myosin is the name given to a solid which separates on the coagulation of muscle-plasma. Muscle-plasma, freed from blood, is a yellowish, opalescent, syrupy fluid, which filters with difficulty and clots spontaneously at temperatures above 0° C. (32° F.). It may be diluted with solutions of varying strengths of several neutral salts, by which its clotting may be delayed and the changes it undergoes may be studied. Muscle-plasma contains a globulin, **myosinogen**, which is a generator of myosin, which resembles fibrinogen and coagulates at 56° C. (132.8° F.). This is converted into myosin on clotting by the action of a specific ferment, and there remains in the solution, after the formation of the clot, myoglobulin and an albumin resembling serum-albumin. Apart from these general reactions, myosin is distinguished by its low heat-coagulation temperature, 56° C. (132.8° F.). It is converted into an insoluble proteid by the prolonged action of water, and into **syntonin** by the action of acids. Globulins closely resembling myosin occur in vegetable protoplasm, and in the cells of the liver. Myosin is readily digested by pepsin, more slowly by trypsin.

Globin is produced by the spontaneous decomposition of hemo-

globin on exposure to the air. It is an insoluble proteid, of which little is known. It is scarcely soluble in dilute acids or alkalies, or in solutions of NaCl.

DERIVED ALBUMINS, OR ALBUMINATES.

There are two forms of these compounds, the **acid-albumins** and **alkali-albumins.** They are obtained by dissolving albumin in acids or alkalies. Some of the acid-albumins contain sulphur, while the alkali-albumins do not. When freshly prepared, they are soluble in dilute acids, alkalies, and alkaline carbonates. Their solutions are precipitated by careful neutralization, by boiling only in neutral solutions, and with difficulty by alcohol.

Globulins are more readily converted into acid-albumins than the native albumins. Coagulated proteids, as fibrin, require acid in a concentrated form. As obtained from the various proteids, the products exhibit certain marked differences, indicating that each proteid yields its own special acid-albumin.

Preparation of Acid-albumin.—Blood-serum, or the diluted white of egg, is digested at 40° to 50° C. (104° to 122° F.) for several hours with 1 per cent. to 2 per cent. of HCl. The solution is filtered, carefully neutralized, and the precipitate collected on a filter and washed with distilled water. It may be rapidly prepared by beating the white of egg with glacial acetic acid. A jelly is thus formed which can be dissolved in warm water, and from this solution the acid-albumin is precipitated by neutralizing and washing as before.

Syntonin is merely an acid-albumin which results from the action of acids on myosin, or muscle-globulin. It has certain properties which distinguish it from the similar products of the action of acids on other proteids. For example: It is soluble in lime-water; it is insoluble in acid sodium phosphate, NaH_2PO_4, while other acid-albumins are soluble. When precipitated from its acid solution by neutralizing, the precipitate is more gelatinous than that of the other acid-albumins, and is less readily soluble in alkalies.

Alkali-albumin may be obtained by the action of dilute alkalies on native albumin solutions, upon coagulated albumin or other proteids. The jelly produced by the action of KOH solution upon white of egg is alkali-albumin. If serum, egg-albumin, or muscle-juice be treated with a dilute alkali, the proteid undergoes a change, and is converted into alkali-albumin. This solution is no longer coagulated by heat. The proteid is entirely precipitated upon neutralization, and the precipitate is insoluble in water and in neutral NaCl solutions, but

is readily soluble in dilute acids or alkalies. It has been a matter of considerable discussion, whether acid-albumin and alkali-albumin, when precipitated by neutralization, are identical or different substances.

Caseinogen and **casein** is a proteid found in the milk of mammals, and until recently classed as an alkali-albumin, but it is now known to be a nucleo-albumin.

Caseinogen exists in milk in the soluble form, or in a state of semi-solubility. Under a high magnifying power, the caseinogen can usually be seen as very fine granular particles, and therefore a portion of it at least must be in suspension, instead of in actual solution. There is a slight difference in the composition and properties of caseinogen of cows' and of human milk, which explains a part of the difference in digestibility of the two. Caseinogen is somewhat richer in nitrogen than alkali-albumin ; it yields sulphur to heated potassium hydroxide, which alkali-albumin does not. It is coagulated by rennin, which is not the case with alkali-albumin. Its solutions do not coagulate on boiling, are precipitated by most acids, but not by simple neutralization in presence of an alkaline phosphate. Potassium ferro- and ferricyanide and dilute sulphuric acid precipitate casein in presence of free acetic acid. Rennet contains a special curdling ferment, **rennin,** as also do gastric and pancreatic juices, which can precipitate casein from alkaline solutions at slightly elevated temperatures.

This precipitation is due to the specific action of an enzyme, which results in the formation of a substance differing essentially from caseinogen. It has been proposed to call the product of rennin coagulation **casein,** and the substance in solution **caseinogen.** The relation of these bodies is similar to that between fibrin and fibrinogen. Simultaneously with the formation of the clot, a by-product is formed having the properties of the soluble albumins. The curd precipitated by acids differs from casein precipitated by rennin in the fact that it is less soluble in acids and alkalies ; casein always leaves a larger amount of residue on ignition. Calcium phosphate seems to play an important part in the coagulation of casein. If the casein be freed from calcium phosphate and dissolved in a dilute alkali, it will not yield a curd with rennin. It may be also stated that caseinogen precipitated by acids instead of by rennin can not be employed for the manufacture of cheese, as it will not "ripen." Cheese can only be made by the use of rennin. When milk is submitted to dialysis to separate the inorganic salts, it yields no clot with rennin ; but if the salts be added again, it yields a clot. The action of calcium phosphate appears to be that it assists in the separation of the clot from the solution. The calcium salt is not alone essential for this, as similar salts of Mg, Ba, or Sr will give similar, though less efficient, results.

Solutions of alkali-albumin can not be made to clot by the action of rennin.

The caseinogen of cows' milk differs from that of human milk in the following particulars : (1) Human milk forms finer coagula than cows' milk, and sometimes not at all, with rennin. (2) In human milk the caseinogen yields a very imperfect precipitation with acetic acid, which is a finely flocculent precipitate as compared with the coarsely flocculent precipitate yielded by cows' milk. The caseinogen can be completely precipitated from human milk only by saturation with $MgSO_4$, and not with acetic acid. (3) Casein from human milk is less soluble in water than that of cows' milk. When digested with gastric juice, caseinogen yields caseoses instead of albumoses, and pseudo-nuclein. Lehman says that cow-casein is a double compound of casein-calcium with calcium phosphate, in which 1.4 to 1.7 per cent. of the calcium is combined directly with the casein. Cow-casein contains about 7.2 per cent. of ash with 6.6 per cent. of Ca_3PO_4, while human casein contains but 3.2 per cent. of Ca_3PO_4.

It is thus probable that the two caseins are chemically different substances.

COAGULATED PROTEIDS.

Very little is known of the chemical characteristics of the proteids after coagulation. These products are produced by heating solutions of the proteids, generally in slightly acid solutions, or by the action of the various agents which have been mentioned above. They are insoluble in water, dilute acids, alkalies, and neutral saline solutions of all strengths. They are soluble only in strong acids or alkalies, though often the prolonged action of dilute acids or alkalies will effect some solution, especially at a high temperature. During these solutions, however, a destructive decomposition takes place, some acid- or alkali-albumin always being produced, together with some peptone and allied substances. The coagulated proteids are readily converted into peptones, at the temperature of the body, by the action of the gastric or the pancreatic juice. All proteids in solution are precipitated by alcohol. If the alcohol be rapidly removed, the proteids are again soluble in water ; but if the precipitate be left in contact with the alcohol for some time, it loses its solubility.

Fibrin is a white, elastic, more or less fibrillated solid, insoluble in water or dilute salt solution. It is soluble in acids (1 to 5 per cent.) with difficulty. With strong hydrochloric acid, it forms a violet solution. When boiled with caustic alkaline solutions, it

forms ammonia and alkaline sulphides. Fibrin may be prepared by whipping blood with a bundle of twigs, and washing the coagulum with water and then with alcohol and ether.

It is doubtful whether fibrin is a single substance, or whether there are several. The solubility and behavior of fibrins depend very much upon the conditions of their formation. When unboiled fibrin is washed until it is white, and digested by active trypsin, it is largely converted into coagulable proteids during the first stages of the digestion. These proteids are globulins, one of which is closely related to paraglobulin, as its saline solutions coagulate at 75° C. (167° F.). A second globulin, the product of trypsin digestion, coagulates at 55° to 56° C. (131° to 132.8° F.), and in this respect closely resembles fibrinogen. Globulins are also produced by the action of pepsin in the first stages of its action upon raw fibrin. If the fibrin is boiled, or treated for some time with alcohol before digestion with trypsin or pepsin, mere traces, if any, of these globulins are obtained. It is possible, therefore, that the globulins obtained by this treatment may be present in the raw fibrin, as such. When boiled with water, or treated for some time with alcohol, fibrin loses its elasticity; its solubility in the various reagents is lessened, and its digestion with pepsin and trypsin is rendered more difficult. It resembles the other coagulated proteids. Fibrin has the peculiar property of decomposing hydrogen peroxide. Pieces of fibrin placed in this fluid seem to undergo no change, but decompose the H_2O_2. Guaiacum is turned blue by fibrin in the presence of H_2O_2 or turpentine, in this respect giving the reaction for blood with this reagent.

In comparing globulin, myosin, and fibrin, they form a series in which myosin is intermediate between globulin and fibrin in its solubility and most of its reactions. Myosin is, in fact, a somewhat more soluble form of fibrin, depositing in clumps or masses instead of in threads or filaments.

ALBUMOSES, OR PROTEOSES.

When any of the proteids above described are submitted to the digestive action of pepsin, trypsin, or certain other enzymes, certain intermediate products are produced in the earlier stages, which finally become peptones. When the digestive fluid employed is pepsin with dilute HCl (0.2 per cent. solution), a small portion of the proteid is first converted into acid-albumin. This may be precipitated by

neutralizing the fluid during the early stages of the digestion. At a later stage of the digestion, this acid-albumin disappears, and other products make their appearance, which are known collectively under the name of albumoses, or proteoses. By the continued action of pepsin and hydrochloric acid, these albumoses are changed into peptones as a final product.

The process above described consists in a gradual hydrolysis of the proteïd molecule, with the result, at first, of a cleavage or splitting of the molecule into two groups of radicals, known as the hemi- group and anti- group These groups give rise to two distinct classes of products. These two groups may be separated by the action of sulphuric acid (3 per cent.) at 100° C. (212° F.), about half of the proteïd going into solution, there remaining (anti- group) a gelatinous mass, insoluble in dilute acids, but readily soluble in a dilute solution of sodium carbonate. It is only slightly digested by gastric juice, but is readily dissolved by pancreatic juice, and converted into anti-peptone. The above-mentioned residue, insoluble in dilute acids, is now generally called **anti-albumid**, but was formerly called hemi-protein. The sulphuric acid solution contains the decomposition products of the hemi- portion of the proteïd molecule—viz., hemi-albumose, hemi-peptone, leucin, tyrosin, etc. Hemi-peptone is gradually changed by the trypsin of the pancreatic juice into simpler crystalline compounds, like leucin, tyrosin, etc., while anti-peptone is incapable of further change by trypsin. The action of pepsin-hydrochloric acid upon albumin can be summarized as follows : The first action is to form acid-albumin. This is then split into two groups of primary proteoses, called *proto- albumoses* and *hetero- albumoses*, of each of which there is a hemi- and an anti- variety. The first of these is produced principally from the hemi- groups of the albumin molecule, with a much smaller amount coming from the anti- groups. The second is produced principally from the anti- groups, a smaller quantity being furnished by the hemi- groups.

The primary proteoses are changed by further action of the pepsin into secondary proteoses or deutero-albumoses, and finally into peptones, of which there are two varieties. The cleavage of the albumin molecule, under peptic digestion, also splits off a certain amount of *anti albumid*, which is further changed into deutero-albumose and finally anti-peptone.

The gastric digestion of proteids is thus seen to be a complicated process. The following scheme will make these changes somewhat clear :

Albumin.
|
Acid-albumin.

(Hemi- Group.)   (Anti- Group.)

Hemi-Proto-Albumose.   **Anti-Hetero-Albumose.**   **Anti-albumid.**
Anti-Proto-Albumose.   Hemi-Hetero-Albumose.

Hemi-Deutero-Albumose. Anti-Deutero-Albumose.   Anti-Deutero-
Anti-Deutero-Albumose. Hemi-Deutero-Albumose.   Albumose.

Hemi-Peptone.   **Anti-Peptone.**   **Anti-Peptone.**
Anti-Peptone.   Hemi-Peptone.
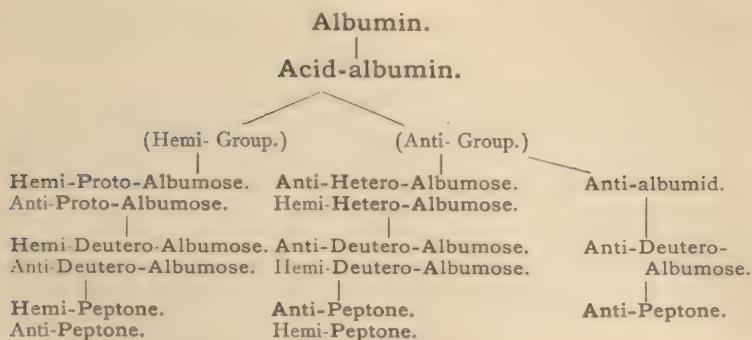
NOTE.—The boldface type indicates that that variety of each product is formed
in largest amount, while the prefixes hemi- and anti- indicate from which group or part
of the molecule each is formed.

When trypsin is employed in the digestion of proteids, the process
is somewhat different, and the decompositions of the proteid are much
more complicated than is the case with pepsin. Instead of acid-
albumin, a small quantity of alkali-albumin is at first formed, together
with more or less coagulable globulin. Albumoses soon make their
appearance, which are somewhat rapidly converted into peptones,
some of which, in turn, are converted into leucin, tyrosin, and other
products. Somewhat similar products of decomposition may be pro-
duced by the action of acids and alkalies alone upon proteids. The
character of the products depends upon the concentration of the acid,
the temperature, and the duration of the action.

Proteids may also be peptonized by the action of water at a high
temperature and under pressure. The albumoses are thus the true
primary products of the hydrolysis of proteids.

The albumoses are best prepared by the action of a small amount
of very active pepsin on a large amount of fibrin previously treated
with 0.2 per cent. HCl at 40° C. (104° F.), or by heating proteids
with water under pressure for several hours at about 150° C. (302°
F.). Under the action of pepsin the fibrin dissolves, and, as soon as
this is complete, dilute solution of Na_2CO_3 is added until the reaction
is faintly alkaline, when the acid-albumin is precipitated. This is
removed by filtration, and the filtrate contains albumose with but a
faint trace of peptone. The primary albumoses (proto-albumose and
hetero-albumose) may be precipitated from this solution by strongly
acidifying with acetic acid and saturating the solution with NaCl.
The albumose, as thus precipitated, may be collected on a filter and

washed with a saturated solution of NaCl. It may again be dissolved in water if desired.

Solutions of albumoses give the following reactions :

First. Acetic or nitric acid, added drop by drop, precipitates primary albumoses in the cold, the precipitate dissolving on warming, to separate again on cooling.

Second. If the solution be slightly acidulated with acetic acid, avoiding all excess, and a trace of potassium ferrocyanide be added, a precipitate forms which disappears on warming, to reappear again on cooling.

Third. On adding caustic soda in excess and a drop of a copper sulphate solution, a rose-red color is obtained. This reaction is also obtained with solutions of peptones, but not with other soluble proteids. (See table, p. 504.)

Fourth. A weak solution of copper sulphate (2 per cent.) precipitates primary but not secondary albumoses.

Peptones.—The gastric, pancreatic, and probably the intestinal juices convert albumoses into a more soluble and diffusible form, called **peptones.** Several different peptones have been described, but some of them are probably mixtures of albumoses and true peptone. Since the conversion is a gradual process of hydration, it is but natural to expect such a mixture. Dehydrating agents, as heat, can reverse the process, and convert peptone into albumin.

The reactions of peptones are mostly negative. Solutions of peptone do not exhibit a viscid character, are not coagulated by heat, nitric acid, or acetic acid and potassium ferrocyanide. Alcohol precipitates them, but the precipitate is soluble in water. Tannin, mercuric chloride, picric acid, and potassiomercuric iodide precipitate them in the cold.

The most marked property is their extreme solubility in water and their comparatively ready diffusibility through animal membranes. Amyloid matter is not converted into peptone by pepsin or trypsin.

Peptones may be separated from albumoses by saturating the cold solution with ammonium sulphate, when the albumoses are precipitated, while the peptones are not. Notwithstanding the formation of peptones in considerable quantities during stomach and intestinal digestion, very little can be found in these localities at any time. They are probably absorbed as soon as formed. It is also a matter of interest that they disappear as soon as absorbed, and are converted back into other proteids as soon as they enter the blood, or probably while passing through the membranes. It is believed that this change is produced by the tissue-cells of the mucous membrane or of the villi.

THE COMPOUND PROTEIDS.

Besides the simple proteids which we have noticed, there are certain well-defined substances found in both plant and animal structures that are composed of compounds of these with some non-proteid body. In this class of substances we will include hemoglobin and its derivatives, to be mentioned when we come to speak of the animal pigments. These are compounds of globulin with an iron-containing pigment.

The compound proteids may be divided into the following groups :

1. Gluco-proteids, including the mucins, mucoids, hyalogens, and phospho-gluco-proteids.

2. Nucleins, or compounds of a proteid with phosphoric acid or nucleic acid.

3. Nucleo-proteids, or compounds of a proteid with nuclein, which, on peptic digestion, leave a residue of nuclein or pseudo-nuclein.

4. Lecith-albumins, composed of a proteid and lecithin.

5. Respiratory pigments, including hemoglobin and its derivatives.

The Gluco-proteids.—These are compounds of a proteid and a carbohydrate.

Mucin occurs in the cement-substance of connective and epithelial tissues. It is also present in the secretions of mucous membranes.

It swells up in a little water and dissolves in a large quantity. Its solutions do not coagulate on heating, and it contains no sulphur. It is insoluble in alcohol, ether, chloroform, or gastric juice.

Its solutions are precipitated by acetic acid, alum, basic acetate (subacetate) of lead, and very dilute mineral acids. Its solutions dissolve oxide of copper, and thus hinder the copper test for sugar, when applied to urine containing an abundance of mucus. The decomposition products of the proteid portion of mucin are the same as those of the proteids.

Mucoids.—Closely related to mucin are certain substances which form ropy solutions, but which are not precipitated by acetic acid. They occur with mucin in submaxillary saliva, in intestinal mucus, the vitreous humor, white of egg, in the umbilical cord, etc. They differ from the true mucins in not precipitating from their alkaline solutions on the addition of acetic acid, or the precipitate is readily soluble in excess of this acid. All these substances are decomposed by dilute acids into a proteid, and a carbohydrate which reduces Fehling's solution.

Phospho-gluco-proteids.—These substances not only yield with acids a carbohydrate, like mucin and mucoids, but, on digestion with pepsin, leave a residue of pseudo-nuclein ; that is, a nuclein-like

body that does not yield xanthin bodies on further decomposition, as do the true nucleins.

Like the nucleins, these bodies contain a large amount of phosphorus.

Nucleins.—These bodies vary in composition when derived from different sources, and there is some diversity of view as to their composition. They are of two kinds—**true nucleins** and **pseudo-nucleins.** The former are derived from nuclei of cells and yield, on decomposition, xanthin bases. The latter include those obtainable from egg-yolk and milk, and do not yield xanthin compounds, but simply a proteid and phosphoric acid.

The true nucleins are composed of a proteid combined with a complex acid called nucleic acid. The nucleins seem to differ from one another in the relative proportions of the proteid and nucleic acid. This acid does not give the proteid reactions. Nucleic acid has a strong affinity for certain basic analin dyes like methyl-green. The nucleins have come into prominence as a remedy for certain diseases. There are four nucleic acids, which can be split up into the four bases —adenin, hypoxanthin, guanin, xanthin, and another acid, which is different in each nucleic acid.

It is claimed by some that there are but two bases in the nuclein of cells, and that the other two are derivatives, as shown in the following reactions:

$$\text{1. } \underset{\text{Adenin.}}{C_5H_4N_4NH} + H_2O = \underset{\text{Hypoxanthin.}}{C_5H_4N_4O} + NH_3.$$

$$\text{2. } \underset{\text{Guanin.}}{C_5H_4N_4ONH} + H_2O = \underset{\text{Xanthin.}}{C_5H_4N_4O_2} + NH_3.$$
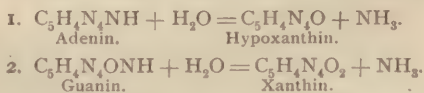
The close relationship of these bodies with uric acid, $C_5H_4N_4O_3$, has already been pointed out. (See p. 468.) It is thus probable that one of the important sources of uric acid is from cell-nuclein.

Nucleo-proteids.—This is a class of bodies composed of nuclein and a proteid (probably globulin), whereas the nucleins are composed of nucleic acid and a proteid. They resemble the globulins in their solubility. They are found, together with nuclein, in living cells, more especially of the glandular organs, such as the thymus, spleen, liver, kidney, etc.

Nucleo-albumin resembles mucin in physical properties, the solutions having the same viscid character, both being precipitated by dilute acetic acid. The viscid appearance of fresh bile is due to nucleo-albumin instead of mucin, as formerly supposed.

When nucleo-albumins are submitted to gastric digestion, the proteid portion of the molecule is converted into peptone, leaving insoluble nuclein. Caseinogen of cows' milk is now regarded as a

nucleo-albumin, for when submitted to gastric or pepsin digestion a residue of pseudo-nuclein is always left undissolved.

Lecith-albumins are a class of complex compound proteids found in certain glandular organs, as the gastric mucous membrane and liver, and in milk. They are supposed to play an important part in cell-nutrition. Hemoglobulin and derivatives are considered among the animal pigments, below.

ALBUMINOIDS OR GELATINOIDS.

Collagens.—Under this head we shall include several groups of more or less insoluble bodies, resembling the true proteids in some particulars, but attacked by the digestive ferments with difficulty.

Most of these bodies, when decomposed by dilute acids and heat, yield leucin and tyrosin.

Collagen is the name given to the substance composing the white elastic tissue of the skin, tendons, etc. When boiled for some hours with water it forms gelatin. **Collagen** and **ossein** seem to be closely allied in both composition and properties. **Ossein** is the proteid basis of bones, and is converted into gelatin by boiling with water. Embryonic tissues, when boiled, yield **mucin** and **chondrin** instead of gelatin.

Gelatin, in the pure state, is a colorless or slightly yellowish, transparent, vitreous, tasteless mass. It swells in cold water, and readily dissolves in hot water or glycerin, forming a thick, viscid solution, which gelatinizes on cooling. Heating to 140° C. (284° F.) or long-continued boiling destroys this power of gelatinizing. It is soluble in dilute acetic and other acids, but insoluble in alcohol, ether, and the oils. Solutions of gelatin dissolve copper oxide with a blue color, which, on boiling, is reduced, but without separation of red oxide; it therefore interferes with the copper test for glucose. An impure gelatin prepared from animal refuse (bones, hides, etc.), when in the dry state, forms glue. **Liquid glue** is a solution of glue in acetic acid. Solutions of gelatin are precipitated by tannic acid, mercuric chloride, alcohol, and chlorine water, but not by acetic acid and potassium ferrocyanide, alum, or acetate of lead. Saturation with $MgSO_4$ or $(NH_4)_2SO_4$ precipitates it. Gelatin is levorotatory.

Chondrin exists in permanent cartilages, and forms gelatin on boiling with water. The gelatin from this source differs slightly from that prepared from collagen or ossein.

Elastin.—This is the characteristic component of elastic tissue, after the removal of gelatin, mucin, fats, etc. It is usually prepared from the ligamentum nuchæ of the ox, which is cut into fine slices,

boiled for three or four days in water, and then for some hours with a
1 per cent. KOH solution, and finally with water. This is then re-
peated with 10 per cent. acetic acid, and finally it is treated for twenty-
four hours with cold 5 per cent. HCl, washed with water, boiled with
95 per cent. alcohol, and extracted for at least two weeks with ether,
to remove the fat. There is left a pale yellowish powder, in which
the fragments of the original elastic tissue may be distinguished under
the microscope. When moist it is yellow and elastic, but on drying
becomes brittle. It may be digested with pepsin or trypsin, and is
readily corroded and dissolved by papain.

Keratin.—This is the chief constituent of hair, nails, feathers,
horns, and epidermal structures in general. It is mixed, however, in
these structures, with small quantities of proteids and other substances,
from which it may be freed by thorough extraction with water, al-
cohol, ether, and dilute acids, followed by digestion with pepsin and
trypsin, when nearly pure keratin remains. The composition of
keratin is closely allied to that of the true proteids.

Neuro-keratin is an allied substance found in brain-tissue.

Chitin, $C_{15}H_{26}N_2O_{10}$, is not found as a constituent of any mam-
malian tissue, but is found in the exoskeleton of many invertebrates.
It is more analogous to the cellulose of plants than to the proteids.
The most convenient source is the shells of crabs and lobsters.

Spongin is the chief constituent of the sponge.

Fibroin, $C_{15}H_{23}N_5O_6$, is the chief constituent of silk, and is covered
with a glue known as sericin, which is soluble in warm soap-water.

Lardacein, or amyloid matter, is an amorphous, friable mass,
occurring in certain regions of the body as a pathological product. It
seems to be a derivative of fibrin. It is generally found as little trans-
parent grains, or corpuscles, somewhat resembling starch-granules.
The usual locations are the liver, spleen, and kidneys. It gives many
of the proteid reactions. It is stained a reddish-brown color with
iodine, which is changed to a violet or blue tint by dilute sulphuric
acid. Anilin-violet stains it rose-red or violet instead of blue. Eosin
stains it a bright red color.

VEGETABLE PROTEIDS.

The amount of proteid matter in plants is less than in animals.
They do not differ essentially in composition or properties from those
found in animals. They occur in solution in plant-juices, or as
composing the protoplasm of the cells, or deposited in the form of
granules, called aleurone grains.

Plant proteids have received less attention than the proteids of animals. Representatives of each of the same five or six classes of proteids above mentioned are to be found.

Vegetable albumins are sparingly found. Most of the proteid substance found dissolved in plant-juices, and precipitated by boiling, is globulin and not albumin.

Plant globulin, or **plant vitellin,** is the most abundant proteid found in plants. This globulin, like animal vitellin, is insoluble in water and soluble in a weak solution of NaCl. It coagulates at about 75° C. (167° F.). This substance, as it occurs in the aleurone grains of many plants, is distinctly crystalline. It is thus the purest native proteid known.

Plant myosin and **paraglobulin** have also been found.

Of the **vegetable albuminates** the two best known are **legumin,** or **vegetable casein,** and **conglutin** of almonds and lupines.

Legumin occurs in the leguminous plants as an alkali-albuminate. It may be obtained from softened peas or beans. It resembles casein in its properties. Some recent investigators claim that it does not occur as an alkali-albuminate in the plant, but as a globulin, which is changed into an albuminate by the method of extraction. Like all the globulins, it is easily soluble in alkalies and acids.

Proteoses, or Albumoses.—Many plants contain proteids of this class. Martin has described four proteoses found in papaw-juice, and two in wheat-flour. In the papaw they are associated with the ferment papain, and are probably produced by the action of this ferment upon the globulins of the plant. Papain acts upon animal proteids in alkaline or weak acid solutions to convert them into proteoses and finally into peptones. It does not form peptone with vegetable proteids. Leucin and tyrosin are formed, however, in small amounts.

Peptones, for the above reason, rarely occur in plants.

Coagulated proteids of vegetable origin are produced by heating the plant, when the albumins and globulins are coagulated. The fibrin-like body formed from wheat-flour by treatment with water, and from which the starch may be washed with cold water, is a compound or mixture of two proteids found in the flour. The proteids in wheat compose about 10 per cent. of the weight of the grain. The most recent investigations show that there are four different proteids present—an albumin existing in from 0.3 to 0.4 per cent. of the weight of the grain, a globulin in from 0.6 to 0.7 per cent., a proteose in about 0.3 per cent., gliadin existing in 4.25 per cent., and glutenin (gluten-casein) in 4.5 per cent. of the grain. **Gluten-fibrin,** or **gluten,** is principally made up of a mixture of the last two

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of these bodies. Gliadin is soluble in pure water, but in the presence of the salts of the flour it forms a sticky, tenacious mass, which adheres to the glutenin, which is insoluble, forming a tough, glutinous mass, inclosing starch to form a dough. By washing or kneading this dough with cold water, the starch may be washed out, together with the other proteids, and gluten is left. Some investigators have claimed the presence of a ferment, while no one has ever isolated it, and some deny its presence or the necessity for it, in the formation of gluten. Gluten is soluble in weak alkalies and acids, and it forms peptones in gastric and pancreatic digestion.

Zein is a fibrin-like proteid found in maize with several other proteids. It is soluble in ordinary alcohol.

Leucosin is an albumin found in rye, wheat, barley, etc.

Edestin is the name that has been given to a globulin found in wheat, rye, barley, and other cereals.

Most of the cereal grains also contain a proteose, probably formed from the other proteids by ferment action.

THE PRINCIPAL ANIMAL PIGMENTS.

BLOOD-PIGMENTS.

The **hemoglobins**, or blood-pigments, form the chief constituent of red blood-corpuscles in vertebrates, and occur in the muscle of mammals and in the blood of a few of the invertebrates. They all crystallize, but not with equal facility. All hemoglobins are of a blood-red or brick-red color when in powder. They contain from 0.4 to 0.6 per cent. of iron, and differ slightly in composition. They are compound proteids.

The crystalline forms of hemoglobins vary in different animals. The crystalline blood-pigments are oxyhemoglobins. Hemoglobin forms a feeble compound with oxygen, which is released by heating its solutions in a vacuum, or in presence of ferrous sulphate, ammonium sulphide, stannous chloride, etc. Reduced hemoglobin and oxyhemoglobin are distinguished by their absorption spectra, the latter showing two such bands separated by a green band, while the former shows but one broad band occupying nearly the position occupied by the greenish-yellow band between the dark ones above mentioned. (See Figs. 10 and 11, Frontispiece.) Hemoglobin unites with nitric oxide, carbon monoxide, hydrochloric acid, hydrocyanic acid, carbon dioxide, etc. Some of these compounds give peculiar spectra : these gases are not easily expelled by oxygen, and hence are deadly poisons when inhaled.

Hematin, $C_{34}H_{35}N_4FeO_5$, is obtained in the form of a salt, by the decomposition of oxyhemoglobin with an acid. It is an amorphous, blue-black mass, with a metallic luster, insoluble in water or alcohol, but soluble in alkalies. It yields two different spectra—one when combined with oxygen and another with carbon dioxide.

Hematin hydrochlorate, or **hemin** crystals, may be obtained by heating hemoglobin, or dried blood, with common salt and glacial acetic acid. It forms thin, rhombic plates, having a brown-red color. The formation of these **blood-crystals** is used to detect blood stains in criminal cases. The drop of dried blood is placed upon a micro-

FIG. 62.—GOWER'S HEMOGLOBINOMETER. A, PIPETTE BOTTLE FOR DISTILLED WATER; B, CAPILLARY PIPETTE; C, GRADUATED TUBE; D, TUBE WITH STANDARD DILUTION; F, LANCET FOR PRICKING THE FINGER.

scopic slide, together with some pulverized common salt, and then treated with glacial acetic acid, and a cover-glass placed upon it. The slide is heated until bubbles appear in the acid, cooled, and examined with a $\frac{1}{4}$-inch objective. The presence of blood is indicated by the presence of the crystals.

The amount of hemoglobin in the blood is most easily determined, for clinical purposes, by the **hemoglobinometer.** The process depends upon the imitation of the color of a standard solution of hemoglobin, or of a colored glass plate, by dilution of a measured volume of blood until its color is that of the standard. Several instruments

based upon this principle have been devised. Of these, one of the simplest is that known as Gower's, represented by figure 62. It consists of two glass tubes of the same diameter. One (D) contains a standard of the tint of normal blood when 20 cubic mm. are diluted to 2 c.c. (1 : 100). It is filled with a glycerin jelly, colored with carmine and picrocarmine so as to get the right tint. The second tube (C) is so graduated that 100 divisions represent 2 c.c. The instrument is used as follows :

The finger is pricked and the drop of blood that issues is drawn into the pipette, shown in the figure, until it reaches the 20 mm. mark. It is then quickly blown out into the tube (C), in which a few drops of distilled water have previously been placed, and is quickly shaken to prevent coagulation. Distilled water is then added until the tint of this mixture is exactly that of the standard in (D) when viewed by transmitted light.

Since average normal blood gives the tint of the standard when diluted to the 100 mark, the degree of dilution used to give that tint, in any given sample of blood, gives the percentage of the normal amount of hemoglobin in that blood. Thus, if the tint of the standard is reached when the sample is diluted to the 70 mark, the blood under examination contains 70 per cent. of the normal amount of hemoglobin. To determine the quantity of hemoglobin, it is only necessary to make the standard color by dissolving a known weight of hemoglobin crystals in water, and comparing with the diluted blood, as above. When the color in both tubes is alike, they contain the same amount of hemoglobin. A rapid approximate estimation of the percentage of corpuscles may be made by Blix's method, or the hematocrit. The blood is mixed with a definite amount of 2½ per cent. solution of $K_2Cr_2O_7$, and centrifugalized. The corpuscles rapidly separate at one end of the tube in almost a solid mass, and can be read off. The average percentage of corpuscles is 48. An exact quantitative estimation is seldom necessary for clinical purposes.

Methemoglobin is a slightly changed derivative from oxyhemoglobin, produced by the action of many reagents, as acids, alkalies, many salts, etc., or by simply exposing a solution of blood to the air for some time. It is characterized by an absorption band not found in fresh blood, and situated between C and D. (See Frontispiece, No. 14.)

Hemocyanin is a globulin-like body found in solution in the blood of some invertebrates. It contains copper as one of its constituent elements, instead of the iron of hemoglobin. It turns blue on exposure to the air, and such blood is blue when oxidized, and colorless when reduced.

Hemochromogen is a pigment prepared from hemoglobin by acids or alkalies, in entire absence of oxygen. The hemoglobin is split into two compounds by the reagents, the one being a proteid and the other the above coloring matter. It is very similar to, though not identical with, hematin.

Hystohematin is the name that has been given to a class of pigments widely distributed in various tissues of both vertebrates and invertebrates. These pigments are regarded as the respiratory elements of the tissues, and play the same rôle there that hemoglobin does in the blood. The best known of these pigments is **myohematin**. It occurs in muscles and probably in other tissues, and is the medium of the absorption of oxygen in these tissues.

Hematoporphyrin, iron-free hematin, $C_{68}H_{74}N_8O_{12}$ (?), is a pigment derived from hemoglobin by dissolving it in strong H_2SO_4 or by heating it with HCl. By diluting this solution with water, the coloring matter is thrown down, especially on neutralizing the acid. This pigment occasionally appears in the urine, as **urohematoporphyrin** or **urohematin**.

Hematoidin, $C_{16}H_{18}N_2O_3$, occurs as reddish, rhombohedral crystals in old blood-clots, in corpora lutea, and in the urine in cases of hematuria. It is believed to be identical with bilirubin, and shows the origin of bilirubin to be probably in the decomposed or disintegrated blood-pigment, separated by the liver.

BILIARY COLORING MATTERS.

There are two pigments obtainable from bile and biliary calculi— viz., **bilirubin** and **biliverdin**. **Bilifuscin, biliprasin, bilicyanin, choletelin, bilihumin,** and **hydrobilirubin** have also been described. The principal one of these, and probably the only one contained in bile when first secreted, is bilirubin, of which the others are derivatives.

Bilirubin, $C_{16}H_{18}N_2O_3$, is met with in the free state in the bile of man and the carnivora, and in ox-bile ; also, together with bilifuscin, $C_{16}H_{20}N_2O_4$, and biliprasin, $C_{16}H_{22}N_2O_5$, in combination with calcium, in biliary calculi.

It is now known to be identical with the red crystalline matter of old hemorrhagic clots, called **hematoidin,** and with **biliphaein, bilifulvin,** and **cholepyrrhin.**

It may be prepared by treating the powdered biliary calculus first with ether, then with boiling water slightly acidified with hydrochloric acid. The residue is washed with pure water, dissolved in hot chloroform, and filtered. The chloroform is distilled off from the filtrate, and the residue treated with absolute alcohol and ether, by which the bilifuscin is removed and bilirubin left. By dissolving this residue in chloroform and setting aside, a part of it may be obtained as a dark-red crystalline powder. It also exists in an orange-red, amorphous powder.

It acts the part of a weak acid, combining with sodium, calcium, barium, lead, etc. The formula of the calcium salt is $(C_{16}H_{17}N_2O_3)_2Ca$.

Bilirubin is closely related to hematin, a derivative of hemoglobin. Moderately strong nitric acid, added to an ammoniacal solution of bilirubin, first colors it green, then blue (**bilicyanin**), violet-red, and finally yellow, the final substance formed being **choletelin,** $C_{16}H_{18}N_2O_5$.

(Gmelin's test for bile.) Nearly the same series of colors are produced by adding bromine to the chloroform solution, with the exception that it finally becomes colorless. Nascent hydrogen converts it into **hydrobilirubin,** $C_{32}H_{44}N_4O_7$ (**urobilin** of urine, **stercobilin** of feces). Hydrobilirubin is a dark-brown, amorphous powder, soluble in alkalies, sulphuric and acetic acids, alcohol, ether, and chloroform. It does not give the play of colors with nitric acid. It is probably formed in the feces by the action of the nascent hydrogen set free by the butyric and putrefactive fermentations upon bilirubin.

Biliverdin, $C_{16}H_{20}N_2O_5$ (or $C_{16}H_{18}N_2O_4$), is an oxidation product of bilirubin, and is readily formed by exposing alkaline solutions of this pigment to the air, or by similar treatment of fresh bile. It forms a green, amorphous powder, insoluble in water, ether, and chloroform. It is soluble in alcohol, acetic acid, and alkaline solutions, and reacts with nitric acid, as does bilirubin. Hydrobilirubin may be prepared from it. **Biliprasin,** $C_{16}H_{22}N_2O_5$, is found in human gall-stones, and **bilifuscin,** $C_{16}H_{20}N_2O_4$, occurs in small quantities in old bile and in gall-stones. According to Städeler, biliverdin is bilirubin + O and H_2O, biliprasin is biliverdin + H_2O, and bilifuscin is bilirubin + H_2O. Viewed in this light, these various pigments would appear to be formed in the following order : Hemoglobin, hematin or hematoidin, bilirubin, hydrobilirubin (urobilin), bilifuscin, biliverdin, and biliprasin.

Fuscin (retinal melanin) is found in the retinal epithelium. **Lipochrin** and **chromophanes** are found in the fat-globules of the retinal epithelium. **Visual purple** is also found in the retina of all vertebrates.

Pyocyanin gives the green or blue color to pus.

URINARY PIGMENTS.

Besides **urobilin,** the urine contains several other coloring matters. Urobilin is derived from hydrobilirubin. It is partly taken up from the bowel, partly formed in the liver or other glandular organs.

Uroerythrin is the pigment precipitated from urine along with uric acid or acid urate of sodium.

Hematoporphyrin is a red coloring matter found in very small amount in normal urine ; but after taking certain drugs, such as salol and other aromatic bodies, it sometimes appears in greatly increased amount.

Pathological urobilin may be detected in fever urines by making them alkaline with ammonia, filtering, and adding a few drops of zinc chloride solution, when it will show a green fluorescence. This urobilin reaction may be obtained more distinctly by shaking the urine with ether, separating the ethereal solution, and, after evaporating the

ether, dissolving the pigment in absolute alcohol. This solution will usually show the green fluorescence. **Urochrome** (thudichum), **uromelanin** (thudichum), **euroerythrin,** and other pigments have been described, but the whole subject is enveloped in much uncertainty and confusion.

Black urine is occasionally seen after breathing arseniuretted hydrogen, in carbolic acid poisoning, and after inunctions of tar.

Melanin (melanogen) is the black pigment of the choroid, melanotic tumors, and skin of the negro.

Pathologically, it is found in the urine of persons suffering with melanotic cancer and sometimes with malaria. It is sometimes deposited in the lungs. Urine containing melanin turns dark on exposure to the air, or, more rapidly, with oxidizing agents, as nitric or chromic acids. Its detection is useful to the physician as an aid to the diagnosis of melanotic cancer of the liver, etc.

IMPORTANT VEGETABLE COLORING MATTERS.

Indigo is a blue coloring matter derived from several species of *Indigofera* and other plants growing in India, Africa, and South America. It exists as a glucoside, called **indican,** which is extracted with water; the liquid, allowed to ferment in the air, deposits the indigo as a blue powder. Commercial indigo is a mixture of several bodies containing about 50 per cent. of indigo-blue or **indigotin,** $C_{16}H_{10}N_2O_2$. (See p. 472.) In dyeing with indigo, the goods are steeped in indigo-white, and then exposed to the air, when indigo-blue is deposited in the cloth. Indigotin has been prepared synthetically from toluene, C_7H_8, a homologue of benzene.

Litmus is a purplish-blue coloring matter obtained from lichens; generally from *Lecanora tartarea*, by steeping in urine and adding lime and potassium carbonate. The mixture is exposed to the air for a few weeks, with frequent stirring, when a thick, blue solution is obtained. The solution is thickened up with plaster-of-Paris or chalk, formed into cakes, and cut into little cubes. The coloring matter of litmus is a weak acid forming salts having a blue color, the commercial product being the potassium salt. With acids, it becomes red from the liberation of the acid. (See p. 441.) **Turmeric** is the root of *Cucurma longa;* it yields a yellow tincture which turns brown with alkalies. The coloring principle is named **curcumin,** $C_{14}H_{14}O_4$. It is used to a large extent to give a yellow color to various articles of food, as mustard, chow-chow, vermicelli, etc.

Saffron, crocus (U. S. P., Br.), is the stigmas of the flower of

Crocus sativa. It yields to dilute alcohol a yellow coloring matter called **polychroit**, $C_{48}H_{60}O_{18}$, a glucoside of **crocin**, $C_{16}H_{18}O_6$.

Tinctura croci is official. (U. S. P., Br.)

Saffron is used to color certain articles of food, as butter, cheese, macaroni, etc.

Annatto is a yellow color obtained from the seeds of *Bixa orellana*. It is used in coloring butter, milk, cheese, etc.

Logwood, hæmatoxylon (U. S. P.), **hæmatoxyli lignum** (Br.), contains a purple dye, hematoxylin, $C_{16}H_{14}O_6 \cdot 3H_2O$, used for purple and black dyes. It is official, and is used as a tonic and astringent. **Brazil-wood** furnishes red dyes and lakes. **Cochineal, coccus** (U. S. P., Br.), the female of the insect *Coccus cacti*, yields to boiling water and alcohol a beautiful red coloring matter, which, precipitated with alum and an alkaline carbonate, yields carmine.

Chlorophyll is the name given to the green coloring matters of the leaves of plants. It occurs as microscopic granules distributed through the cell-protoplasm in all the green portions of the plant. It may be extracted with alcohol, ether, and benzene.

Very little is known of this body, but it seems to be composed of two coloring matters—a blue and a green. It contains iron, and possesses the power, under the influence of sunlight, of decomposing CO_2 and uniting the carbon to the elements of water. The yellow color of autumn leaves is due to **xanthophyll**, an oxidation product of chlorophyll.

POISONS AND THEIR ANTIDOTES.

Of the emergencies which arise in every-day life, or even in the practice of the young physician, none are more embarrassing than acute poisoning. The word poison, to many people, carries with it an idea of horror and panic. The pharmacist is often consulted in haste, or may be called upon to render temporary aid until the services of a physician can be secured. He may in such cases render great service by administering the proper antidote, and thus saving valuable time. Even the physician is liable to something akin to alarm, when he comes into the presence of a victim of a violent poison. It is for these reasons that we introduce a few of the most common poisons, with their antidotes. We do not intend to give a complete guide to the treatment of cases of poisoning, but merely a few simple rules to be remembered as first aids to those suffering with acute poisoning.

The first thing to be considered is the **symptoms of poisoning.**

Not infrequently persons claim to have taken poison when such is not the case. Or, suspicious friends fear that poison has been taken. The author has often met with cases of this kind, where a knowledge of the symptoms of poisoning has saved the patient a very disagreeable experience, and the physician a great deal of trouble and future chagrin. The physician should be familiar with the nature and action of poisons, the symptoms which they produce, the circumstances which retard or otherwise modify their action, their chemical and physiological antidotes, the pathological changes they induce, and the methods of combating these results. It is our purpose here to name a few of the symptoms of poisoning, and then to offer a few hints as to antidotal treatment.

The chief characteristics of poisoning are more or less severe symptoms coming on suddenly or within a few hours after taking some substance or fluid into the stomach, the individual being previously in a state of health. These symptoms usually increase steadily and uniformly, and tend to prove rapidly distressing or fatal. The symptoms may be greatly varied as to time and severity by the quantity or form in which the poison is administered ; the state of the stomach, whether full or empty ; the condition of the person, whether asleep or awake ; and a certain idiosyncrasy of the individual. The symptoms which should arouse suspicion of acute poisoning are the sudden onset of pain in the region of the stomach of a healthy person, especially of a " burning pain," accompanied by dryness of, or a metallic taste in, the throat ; more or less vomiting; great prostration of the vital powers; a deathly or cadaveric aspect, or an expression of great fear or concern ; the rapid intervention of coma, and speedy death. If all, or the greater number of the above symptoms are present in any case, there is reason for suspicion, and the physician should govern himself accordingly. (See remarks under Arsenic, p. 193.) Poisons may, for convenience, be divided into the following five classes, based upon their effects upon the human subject: (1) corrosives; (2) irritants; (3) neurotics; (4) septic poisons; (5) gaseous poisons.

Corrosive Poisons.—To this class belong those poisons which exert principally a local action upon the tissues with which they come in contact. The most important of this class are corrosive sublimate, $HgCl_2$; the concentrated mineral acids (sulphuric, hydrochloric, nitric) and oxalic acid ; the alkalies and their carbonates (potassium, sodium, and ammonium hydroxides and carbonates) ; corrosive salts, as bisulphates of the alkaline metals, alum, nitrate of silver, chloride of zinc, butter of antimony, $SbCl_3$. Carbolic acid is a violent corrosive when concentrated, and also has a remote effect

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upon the system after being absorbed. The symptoms of corrosive poisoning follow immediately after taking the poison, and are a sense of acid, alkaline, or metallic, burning pain in the mouth, throat, gullet, and stomach, usually inducing vomiting, which, however, does not relieve the distress. The pain soon extends over the entire abdomen, and is accompanied with symptoms of shock or collapse. There may be staining of the fauces or mouth.

Irritant Poisons.—Irritant poisons give rise to pain in the stomach of a burning character, usually coming on some minutes or hours after taking the poison. In this respect, they differ in their action from the corrosives. The pain is accompanied, or followed, by vomiting, faintness, purging, and tenesmus; the evacuations being often tinged with blood. The pulse is weak or irregular, and there is frequently severe headache. Death is usually caused by collapse, convulsions, or by inducing severe inflammations, which wear the patient out, after a variable period of time. Some have, also, a specific physiological action, besides their irritant action. The following are the more common irritants: Dilute mineral acids, concentrated organic acids, lime, zinc, copper, barium, silver, and mercuric salts; all compounds of arsenic and antimony; phosphorus, iodine, bromine, etc. Many kinds of food may, under certain conditions, become irritant poisons. Meat, fish, lobsters, tomatoes, etc., especially after having been canned and then exposed to the air. (See Ptomaines.)

Neurotic Poisons.—The neurotics exercise their action through the nervous system, and, therefore, only after absorption into the circulation. They rarely exert any local action. The neurotics are sometimes subdivided as follows:

	EXAMPLES.
Narcotics, or those producing sleep, ...	Opium.
Anesthetics, or those producing insensibility, ...	Chloroform.
Inebriants, or those producing intoxication, ...	Alcohol.
Deliriants, or those producing delirium, ...	Hyoscyamus.
Convulsives, or those producing spasms, ...	Strychnine.
Hyposthenisants, or those producing death by syncope, ...	Prussic acid.
Depressants, or those producing marked depression, ...	Nicotine.

Septic Poisons.—To this class belong certain poisons introduced into the body through abrasions of the skin, open wounds, or by the fangs or stings of venomous animals or insects. In many respects these poisons resemble in their action the depressing narcotics.

Poisonous Gases.—To this class belong carbon monoxide (charcoal fumes), carbon dioxide (choke-damp), marsh-gas (fire-damp),

illuminating gas, hydrocarbon vapors, sewer-gas, confined air of living apartments, and noxious gases and vapors from manufacturing establishments.

TREATMENT OF ACUTE POISONING.

In every case of acute poisoning, or where the symptoms and circumstances indicate that a poison has been taken, the following is the course to pursue :

1. Get the poison out of the system as soon as you can, or neutralize it, if it be a caustic.

2. Neutralize what you can not remove.

3. Favor the natural elimination of the poison.

4. Combat any dangerous symptoms as they arise.

The first of these steps may be secured in one of three ways—viz., by the use of **emetics,** or the **stomach-pump,** or the **stomach-tube.** If a stomach-pump is not at hand, or in case corrosives have been swallowed and there is danger of doing damage in inserting it, the stomach-tube may be introduced through the mouth or even through the nose. By attaching a funnel to the upper end of this, tepid water may be run into the stomach. On now turning the person upon his face or lowering the end of the tube, it acts as a siphon to run the water out. Repeat this process several times as in the process of **lavage,** or until you are sure all poison is removed from the stomach. In the absence of a funnel, make as a substitute a cup-shaped cavity about the upper end of the tube with wax, putty, or wet clay. The proper antidote or an emetic may be dissolved in the last water used.

THE PRINCIPAL EMETICS.

Zinc Sulphate.—Give 20 grains at once, or dissolve ½ drachm in 2 ounces of water, and give a tablespoonful every fifteen minutes.

Copper Sulphate.—Give 5 grains every fifteen minutes, or, still better, 10 grains at once, followed by tepid water.

Alum.—A tablespoonful, given in syrup or honey.

Mustard (ground).—A dessertspoonful stirred in tepid water and quickly swallowed. Very efficient, and is somewhat stimulating.

Apomorphine.—Give $\frac{1}{16}$ of a grain hypodermically.

Syr. Ipecacuanha.—Used mostly for children. Is depressing. One fluidrachm every fifteen minutes to a child two years old, until emesis is produced.

Tepid Water.—Drink copiously and until emesis occurs. It may be assisted by tickling the throat with a feather or the extended finger.

Common Salt.—A tablespoonful in a pint of lukewarm water is often effectual.

SPECIAL POISONS AND THEIR ANTIDOTES.

THE CORROSIVE POISONS.

Strong Mineral Acids.—Sulphuric, hydrochloric, nitric. *Symptoms :* Staining of mouth or throat ; immediate pain ; vomiting ; great prostration.

Antidotes.—Chalk, lime-water, whitewash, magnesia, plaster from the wall, baking-soda, soap. Then give oil freely, and mucilaginous drinks. **Do not give emetics or use stomach-pump. All antidotes must be well diluted before they are given.**

Corrosive Vegetable Acids.—Oxalic, tartaric, acetic. *Symptoms :* Burning pain, constriction in throat, and usually vomiting. Extremities cold ; countenance livid.

Antidotes.—Same as for mineral acids, except in the case of oxalic acid. When this acid is suspected to have been taken, use lime-water or chalk only. Then give mucilaginous drinks and stimulants.

Carbolic Acid (Phenol) and Creosote.—*Symptoms.*—Pain in stomach and whitened stains in mouth ; odor ; contracted pupils ; coma ; death by collapse.

Treatment.—Oils, then emetics or stomach-tube, unless the quantity taken was large and in the pure state. Sodium sulphate in solution has been recommended. A mixture of olive and castor oils, with magnesia in suspension. Albumin of eggs given freely. Treat the collapse by diluted whisky and by injecting stimulants.

Caustic and Carbonated Alkalies.—*Symptoms.*—Acrid, burning taste in the mouth, throat, esophagus, and stomach ; hoarseness ; dyspnea ; vomiting of blood and mucus ; surface clammy ; pulse rapid ; pain over abdomen, and diarrhea.

Treatment.—Well-diluted vegetable acids, such as vinegar, lemon-juice, tartaric or citric acids ; fixed oils, such as castor, linseed, olive, or cod-liver oil. Mucilaginous drinks may be given freely. Do not give emetics or use stomach-pump.

IRRITANTS.

For general symptoms, see page 530.

Antimony, Tartar Emetic, Wine of Antimony or Oxide of Antimony.—*Symptoms.*—Metallic taste ; nausea ; violent vomit-

ing; burning heat and pain in the stomach; purging; cramps, cold perspiration, and great debility.

Treatment.—Assist the vomiting by draughts of warm water, or mucilaginous drinks, such as flaxseed-tea. Then give a cup of strong tea, or an infusion of oak-bark, or a solution of tannin. This may be followed by opiates and stimulants.

Chloride of Antimony, Butter of Antimony.—*Symptoms.* —Same as above, but more caustic.

Antidotes.—Magnesia, with milk and water, baking-soda, tannin, as above, for tartar emetic.

Potassium Bichromate.—*Symptoms.*—Violent purging; painful vomiting of yellow vomit; dilated pupils; cramps in the legs; great depression.

Treatment.—Free use of lime-water, or magnesia in milk.

Arsenic, White Arsenic, Arsenous Acid.—*Symptoms.*— Come generally within a half-hour, but may be delayed two or three hours. Faintness; nausea; constant vomiting; burning pain in the stomach, increased by pressure, and soon extends over abdomen; headache (frontal); diarrhea; great thirst; catching, painful respiration; quick, feeble pulse; cold extremities, and anxious countenance. Death by collapse within twenty-four hours.

Treatment.—Expel the poison by thorough emesis. Promote the sickness by free use of albuminous or mucilaginous drinks. As an antidote, give raw eggs, beaten up in milk; freshly precipitated ferric hydrate or ferric hydrate with magnesia. The first is made by mixing together 100 c.c. of **liquor ferri tersulphatis** (U. S. P.), diluted with 1000 c.c. of cold water and 110 c.c. of **ammonia water** diluted with 250 c.c. of water. Let settle and wash it by decantation, filter through muslin, and shake the precipitate up with 250 c.c. (1 tumblerful) of water.

Ferric hydrate with magnesia is prepared by shaking up 10 gm. of calcined magnesia in a quart bottle with about 800 c.c. of water until a smooth mixture is obtained; add 50 c.c. of solution of ferric sulphate (U. S. P.), and shake again until a uniform smooth mixture is obtained, when it is ready for use. Solution of dialyzed iron has been used with success. These should be followed by stimulants, well diluted.

Metallic Salts, Alum.—Alkaline bicarbonates, baking-soda.

Soluble Barium Salts.—Soluble sulphates, Epsom or Glauber's salt. Then give emetics.

EMETIC POISONS.

Soluble Copper Salts.—Albumin, white of egg and milk, baking-soda, followed by an emetic.

Iron, Green Vitriol, Persulphate of Iron.—Baking-soda and emetics or stomach-tube.

Lead, Sugar of Lead, White Lead.—Solution of Epsom or Glauber's salt given with raw eggs. Then give emetics, followed by castor oil.

Mercury, Corrosive Sublimate.—Albumin, white of egg, flour and milk, followed by emetics or stomach-pump, unless the poison was taken in a concentrated form. Then do not use the pump.

Silver Nitrate, Lunar Caustic.—Common salt, then emetics.

Zinc Chloride, Soldering Fluid, Burnett's Fluid.—Baking-soda, milk, white of egg, tea, decoction of oak-bark. Give opium to relieve the pain, then emetics if necessary.

Tin, Chloride of.—Baking-soda, magnesia, milk, and white of egg.

Iodine.—Most common from the tincture. Give boiled starch-paste, made thin enough to drink. In urgent cases use starch or flour, with cold water. Produce vomiting or use the stomach-tube.

Phosphorus, Rat-poison.—Has no true chemical antidote. Magnesia, milk of magnesia, chalk, or lime suspended in gruel; turpentine. Give no fixed oils. Produce vomiting or use the stomach-tube or pump.

Poisonous Meat, Fish, Lobsters, etc.—*Symptoms.*—Nausea and vomiting three to four hours after taking food, gastro-intestinal irritation, great depression, scarlet rash at times, convulsions in young subjects, pupils either dilated or contracted. Recovery usual.

Treatment.—Encourage vomiting by copious drafts of warm water; counteract depression with diluted brandy or whisky; relieve pain with opium or one of its preparations. Apply hot fomentations to the abdomen. When vomiting ceases, give castor oil or other laxatives.

NEUROTICS.

Narcotics — Opium, Morphine, Laudanum, Paregoric, Soothing Syrups, Quieting Cordials, etc.—*Symptoms.*—Appear in twenty to thirty minutes. Commence with giddiness, drowsiness, stupor, insensibility, with slow and stertorous breathing, weak pulse, contracted pupils, not reacting with light; surface sometimes cold, sometimes bathed in sweat; countenance livid. There is occasionally vomiting or convulsions preceding death.

Treatment.—First empty the stomach of any poison still remaining

unabsorbed, by emetics or the stomach-pump or tube. The patient is to be kept awake by forced walking, by the cold douche, or flagellations with wet towels. Faradic electricity may be applied to the spine. Give strong coffee in abundance. Atropine hypodermically, in $\frac{1}{100}$-grain doses, repeated until the pupils show its effects.

Anesthetics—Vapors of Chloroform or Ether, Chloral, Methylene Dichloride, Nitrous Oxide, etc.—Pure air, cold douches, artificial respiration, hypodermic injections of brandy, aqua ammoniæ (diluted), nitrite of amyl or nitroglycerin. Galvanism or faradism may be employed, if the instruments are at hand, but are of doubtful benefit.

Inebriants — Alcohol, Cocculus Indicus, Nitrobenzene (Essence of Mirbane), Anilin, etc.—Emetics or stomach-pump, when there is reason to believe that any poison remains unabsorbed ; then ammonium carbonate, hydroxide or acetate well diluted. Treat the narcosis as under opium.

Hyposthenisants or Syncopants—Prussic Acid (Hydrocyanic Acid), Potassium Cyanide, Laurel-water, Peach-pits, Cherry-pits, Plum-pits, etc.—No chemical antidote. Emetics or stomach-pump, where there is time. Cold affusions to the face and neck, inhalations of ammonia ; spirits of ammonia or nitroglycerin should be given internally, with brandy.

Aconite (Monkshood, Wolfsbane, Blue Rocket).—*Symptoms.*—Heat, numbness and tingling in the mouth and throat, giddiness, loss of muscular power, sometimes delirium or purging. The skin is cold, the pulse extremely feeble, breathing oppressed. Death by collapse or asphyxia.

Treatment must not be delayed. Emetics or stomach-pump. Give castor oil, animal charcoal, or strong coffee. Stimulants will be needed—brandy, ammonia, nitrite of amyl, nitroglycerin. Artificial respiration if necessary.

DELIRIANTS.

Belladonna (Deadly Nightshade).—*Symptoms.*—Dryness of fauces, thirst, flushing of face, dilatation of the pupil, double vision, giddiness, indistinct vision, delirium and stupor, or occasionally convulsions. Symptoms appear in a half-hour after dose.

Treatment.—Stimulants, emetics; morphine acts well in some cases.

Stramonium (Thorn-apple, Jamestown Weed).—Fruit and leaves are poisonous. *Symptoms :* Same as belladonna.

Treatment.—As in belladonna.

Hyoscyamus Niger (Henbane).—*Symptoms.*—Giddiness, ex-

citement, sense of weight in the head, drunkenness, delirium, dilated pupils, double vision, ending in coma.

Treatment.—Stomach-pump, emetics, stimulants, and full doses of castor oil.

NEUROTICS PRODUCING CONVULSIONS.

Nux Vomica, Brucine, and Strychnine.—*Symptoms.*—Intense bitter taste, followed in a few minutes by difficult breathing, stiffness in neck, muscular twitchings, quivering of frame. The head is drawn back, the body arched backward. The face becomes dusky and drawn. Soon there are distinct spasms and great fear of death.

Treatment.—Emetics or stomach-pump before spasms ; then tannin, tea, oak-bark tea. Keep the patient warm and quiet. Chloroform or chloral to control the spasms.

DEPRESSANTS.

Digitalis (purple foxglove), tobacco, lobelia, colchicum (meadow saffron), white hellebore.—*Symptoms.*—Those of great depression, vomiting, irregular heart-action.

Treatment.—Stimulants, emetics (mustard) and purgatives. Use stimulants freely. Wash out the stomach if seen in time, or give a mustard emetic.

Bites.—First wash thoroughly, then paint with carbolic acid ($\frac{1}{4}$ strength) or tincture of iodine. Tie a handkerchief tightly above wound, until the above applications or strong nitric acid can be applied. Give alcohol freely in bites of snake, scorpion, tarantula, etc.

Stings.—Extract " stinger " if left behind. Apply mud, or a paste made of baking-soda, or wash with weak ammonia water.

Poisoned Wounds,⎫ —Apply carbolic acid ($\frac{1}{4}$ strength),
Dissecting Wounds,⎬ or paint the wound and around it with
Infectious Diseases.⎭ tincture of iodine. Give stimulants internally.

Poisonous Gases—Sulphuretted Hydrogen, Chlorine, Bromine, Carbon Monoxide and Dioxide, Nitrous Fumes, Illuminating Gas, Sulphurous Oxide, etc.—See Special Gases in text.

Treatment.—Fresh air, rest, and mild stimulation. Artificial respiration when necessary.

INCOMPATIBLES.

Substances are said to be chemically incompatible when, on being mixed together, they react upon each other so as to cause an entire change in the properties of the substances so mixed. They may cause the evolution of a gas, an explosive mixture or compound, a poisonous or very active substance formed from comparatively inert ones, or a precipitation of one or the other of the ingredients in the new compounds formed.

Sometimes two or more substances are brought together with the intent of producing a new substance different from either; as $2KI + HgCl_2 = HgI_2 + 2KCl$. This can hardly be regarded as an incompatible mixture.

Of physiological and therapeutical incompatibility we shall have nothing to say here. The student will find the following rules of value to him in the beginning:

1. A free acid is incompatible with the alkaloids and the metallic hydroxides and carbonates. The three mineral acids displace the organic acids from their salts. The converse of these statements is also true—*i. e.*, metallic hydroxides and carbonates are incompatible with the acids.

2. If two substances, when mixed, can form an insoluble third body, or can react so as to generate a gas, they are incompatible.

A knowledge of the solubility of the ordinary salts is, therefore, of great importance to the physician. For example, lead or barium can not exist in a solution with a sulphate; silver, lead, or mercurous mercury can not exist in a solution with a chloride.

Substances are, therefore, incompatible with their tests and antidotes.

3. The alkaline hydroxides and carbonates are incompatible with the salts of the alkaloids and most salts of the heavy metals.

4. Iodides and bromides precipitate most of the heavy metals, and are therefore incompatible with them.

5. The vegetable astringents and bitters owe their properties largely to their gallic acid and tannin. Tannin and most vegetable astringents precipitate the heavy metals from their salts, and are therefore incompatible with them.

6. Powerful oxidizing agents (strong nitric acid, potassium permanganate, hydrogen peroxide, chlorine, the hypochlorites, potassium chlorate, etc.) should not be mixed with easily oxidizable organic substances, for fear of forming explosive compounds.

7. The two principal solvents of the U. S. P. are alcohol and water. Each of these has its own class of easily soluble bodies. These bodies are often precipitated from their solutions in either of these solvents by the addition of the other. Thus, the tincture of iodine, camphor, essential oils, the gums and gum-resins, aloes, etc., are precipitated or rendered unsightly by the addition of water or watery solutions of drugs or chemicals.

8. There are some solutions that should always be prescribed alone, or in a plain watery solution, as they readily decompose. Among these may be mentioned the compound syrup of hypophosphites; Fowler's, Donovan's, and Lugol's solutions.

These few rules will serve to call the student's attention to the subject, and to the general principles of incompatibles.

PART V.

PHYSIOLOGICAL AND CLINICAL CHEMISTRY.

Origin of Vegetable Energy.—In the consideration of living bodies we are led in the outset to divide them into two distinct classes—**plants,** which grow silently under the action of sunlight, and **animals,** which also grow, but manifest their impressions and their will by active movements. This difference is not well marked in all cases, however, as plants are known to exhibit active movements.

The difference between plants and animals is more clearly defined by the character of their food, and the chemical processes which accompany their growth.

The vegetable receives its energy principally from the sun's rays, and feeds upon substances from the mineral kingdom, which are destitute of potential energy. With these substances, CO_2, N, and H_2O, it undertakes to build up an organism.

In order to do so, the absorption of the energy of heat and light is necessary.

These it obtains from the sun, or from some artificial source of light and heat which can take its place. By the aid of these, it chemically combines inert bodies into potential organic substances.

Animals, on the other hand, decompose and render sensible the potential energy stored up in organic substances prepared by the plant. This energy they convert into kinetic energy (heat, nervous energy, and muscular movement). At the same time they eject the used-up products in the chemically inert form of CO_2, H_2O, and urea, suited for the use of the plant.

In a word, **the animal lives on the energy stored up by the plant.** When an animal respires it absorbs a quantity of oxygen which varies from 0.01 to 0.30 of its weight in every twenty-four hours. Almost all of this oxygen is used to produce CO_2 and H_2O with its combustible matters. This is the principal source of its energy. Plant cells also respire in the same way and for the same purpose as animal cells, and, in doing so, use up a part of their stored energy, in exactly the same manner as do animals, by oxidation.

The functions of the protoplasm in plants require the expenditure of energy, and this energy is produced by the oxidation of stored combustibles. In the plant, then, we have two processes going on at the same time—the taking-in of CO_2 and H_2O and the construction of complex organic compounds from them, and the burning-up of a portion of these compounds to furnish the necessary vital energy to carry on its functions, with the exhalation of CO_2 and H_2O. The balance, however, is in favor of the first of these processes, during the day-time; but at night the plant lives like an animal, borrowing its energy from the combustion of its reserves. This fact is shown by the increase of temperature of certain plants at night, and of flowers just at the moment of expanding, or in the heat developed by the sprouting of grain, when the only source of energy is the decomposition of reserves.

Chlorophyll.—When the green parts of a plant are exposed to air and sunlight, they have the power in some way of absorbing the small amount of CO_2 from the air, and returning oxygen to the air. If we examine the plant for the carbon, we find a series of bodies which have been studied under the name of carbohydrates—viz., dextrose, levulose, sucrose, starch, etc.

The first of these substances formed, so far as we can learn, is dextrose or levulose.

We also find that certain nitrogenous products are formed. The plant usually gets its nitrogen in the fully saturated or chemically inert form—*i. e.*, ammonia, nitrates, and possibly urea and amids or amins found in the soil. It is probable that most of these amid bodies are converted into nitrates before being absorbed by the plant.

The mechanism that causes the decomposition of water and carbon dioxide has been proven to be the green coloring matter of the leaves, under the influence of light.

This coloring matter, or **chlorophyll,** will produce this change when exhausted from the leaf with alcohol or petroleum ether. The rapidity of the absorption of CO_2 and the evolution of O is proportional to the intensity of the light.

The light from an incandescent electric light, or a strong gas-light, will also cause the change.

The reaction between CO_2 and H_2O that takes place, by which CO_2 disappears and oxygen is evolved, may be represented as follows:

$$CO_2 \quad + \quad H_2O \quad = \quad O_2 \quad + \quad C{=}O\substack{H\\H}$$

$\quad$ 1 volume. $\qquad\qquad\qquad$ 1 volume. $\quad$ Formaldehyde.

There are reasons for thinking that this reaction does not exactly

represent the change that takes place, but that the chlorophyll, under the action of the sun's rays, combines with hydrogen to form a hydride.

The hydrogen is obtained by the decomposition of H_2O and the liberation of oxygen.

This hydride of chlorophyll, or **chlorophyllin**, gives up its hydrogen to the CO_2, according to the following reaction :

$$H_2 + CO_2 = COH_2 + O.$$
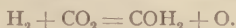
In either case, the first compound formed is formaldehyde, which by polymerizing forms $C_6H_{12}O_6$, or—

$$O = \overset{\displaystyle \overset{H}{\underset{H}{C}}}{C} - \overset{\displaystyle \overset{H}{\underset{H}{O}}}{C} - \overset{\displaystyle \overset{H}{\underset{H}{O}}}{C} - \overset{\displaystyle \overset{H}{\underset{H}{O}}}{C} - \overset{\displaystyle \overset{H}{\underset{H}{O}}}{C} - \overset{\displaystyle \overset{H}{\underset{H}{|}}}{C} - OH$$
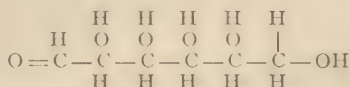
It is thus that the plant prepares sugars, starch, and cellulose, by the polymerization of formaldehyde, and then slight changes in the hydration or dehydration of the product.

The organic products of plant synthesis can be grouped into the following five classes :

1. Alcohols, the sugars, and other carbohydrates.
2. Fats.
3. Hydrocarbons.
4. Proteids.
5. Nitrogenous non-proteid substances.

Assimilation of Nitrogen.—It has been proven by many series of experiments that plants can not, to an appreciable extent, assimilate free nitrogen from the air.

The present state of our knowledge teaches us that plants receive the most of their nitrogen as nitrates and ammonia. By far the largest absorption is as nitrates. These nitrates are produced in the air by electrical discharges and the evaporation of saline waters. (See p. 170.) A considerable production of nitrates takes place in arable soils under the influence of specific organisms which act upon ammonia and nitrogenous matters found in such soils. This organism is known as the **nitrifying organism,** and is always present in soils containing vegetable matter. (See p. 558.)

It is probable that plants can absorb urea and some other soluble nitrogenous bodies of animal origin to a slight degree, but they are quickly transformed in the cells of the roots.

As we are not acquainted with the constitution of proteids, we can not follow the reactions for the building-up of these bodies in the

plant. We do know by experience that plants thrive best on nitrogen in the form of nitrates; that the nitrates enter the circulation and reach the leaves, where they meet with very strong reducing agents in formaldehyde and dextrose. This reduction probably takes place as we see it in warming alcohol with nitric acid, with the production of hydrocyanic acid, formic acid, and water. This reaction takes place at about 35° to 40° C.—*i. e.*, at summer temperature.

We may represent the reaction, as it would occur in the leaf as follows:

$$2HNO_3 + 5COH_2 = 2HCN + 3CO_2 + 5H_2O.$$
Nitric Acid. Formaldehyde. Hydrocyanic Acid.
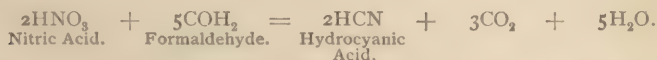
The presence of hydrocyanic acid is well known in the almond, laurel, rose, peach, and many other leaves, fruits, and flowers.

Again, it has been shown that hydrocyanic acid, in the presence of water and formaldehyde, can form certain amids which have been recognized as among the decomposition products of albumin. It is probable, then, that the origin of albuminoid bodies in plants is that here indicated in brief outline, and represented by the following empirical reaction:

$$66CH_2O + 17CNH = C_{62}H_{103}N_{17}O_{22} + 21HCOOH + 2H_2O.$$
Albumin (?). Formic Acid.

The albumin once formed, it can be transformed into other proteids. In a brief way, then, we have traced a few of the synthetic reactions by which plants prepare their reserves of potential organic bodies, or bodies that on oxidation in the animal body, when used as food, can give out heat and nervous and muscular energy.

We have thus the source of energy of animal life; for animals subsist upon the products prepared by plants, either directly, or subsist upon animals which in turn feed upon the stores of starch, gum, sugar, and albuminoid bodies prepared by plants. It will be noticed that the edible parts of plants are the fruits, tubers, or root-stalks, in which the plant has stored these reserves intended for the nourishment of the new germ, when needed to start it in its growth.

Animal Synthesis.—We have seen that the general result of plant growth is synthetical. That of the animal is, in the main, destructive or analytical. In the animal, however, we have synthetic processes, which resemble those of the plant. There are a few animals whose cells possess chlorophyll (*Hydra viridis*). They behave like plants in the sunlight, giving off oxygen and storing up carbon. The formation of fat in the animal body out of albuminoids and carbo-

hydrates is probably a synthetic process.   Animals find it necessary to store up reserve products, and they first convert a part of the potential energy of their food into kinetic energy, and then reconvert it back into potential energy, storing it up in the form of adipose tissue. When the food taken furnishes more energy than is required for present needs, the excess is partly stored up in the form of fat, to be liberated for use when the supply is deficient.

Proximate Principles.—When animals take food composed of the carbohydrates, fats, and proteids, they first get them into a soluble and diffusible form, then absorb them into their circulation. Then there begins a process of assimilation or appropriation.

The animal foods usually consist largely of proteid, fatty, and mineral matters, except in case of milk, which contains all of the classes above mentioned, or it is what has been called a perfect food. Although we take as food various mixtures of vegetable and animal tissues and products, we may divide the **proximate principles** into **carbohydrates** (including alcohols, starch, sugars, and gums), **fats, albuminoids,** or **proteids,** and mineral salts.   Each of these has its special uses in the economy, and all of them are necessary to the maintenance of perfect health.   If either of them is lacking in our food, the body can, for a time, overcome the deficiency by trans-forming the others into a substitute for that which is missing.   It is found, however, that this is always attended with loss of energy and well-being.

Origin and Rôle of Inorganic Substances in the Human Body.—Besides the organic matters of which we have briefly traced the origin, there exist in human tissues certain inorganic or mineral matters, which, from their constant presence, must have an important office to perform.   The human body, as a whole, contains about 70 per cent. of water and 30 per cent. of solid matters.   The amount of ash left on burning an adult body is from 3 to 5 per cent.   There is, therefore, about a fourth of the body made up of dry organic matter.

Gaseous Matters.—Oxygen, partly combined and partly in solution, is found in the blood and in almost all the liquids of the body.   It unites in the blood with the hemoglobin of the red blood-cells, which renders it active and carries it to all the tissues.

In this manner it is brought in contact with the oxidizable products of the destruction of proteids, and burns them, and assists all the tissues in disposing of waste products of cell-action.   An adult absorbs from 770 to 850 gm. of oxygen daily, and exhales by the lungs 540 to 720 gm. as CO_2; a part of the remainder is exhaled by the skin in the same state, and a part is converted into water, urea, and other oxidation products.

The oxygen excreted is about one-fifth more than we inhale, the excess coming from the food taken.

Nitrogen is found dissolved in the blood and other fluids, and is contained in all cavities which are filled with gas. In combination it assists very largely in making up the tissues.

Carbon dioxide is met with in expired air, and in the gases of the intestine, and in solution in many of the fluids of the body. In the blood, saliva, lymph, bile, and other fluids, it is found in combination as carbonates of the alkaline and earthy metals.

In the blood it is also found combined with the alkaline phosphates. One molecule of sodium phosphate, which alkalinizes the blood, combines with $2CO_2$. This weak compound can be decomposed and the CO_2 expelled by passing through the fluid an inert gas at $37°$ C. ($98.5°$ F.), or by the presence of oxygen combined with hemoglobin.

It also forms weak combinations with serum-globulin of the blood. When diluted with water and heated, or when put in a nearly complete vacuum, these compounds part with the carbon dioxide. The CO_2 is carried from the tissues to the lungs in these weak combinations.

Hydrogen is found free in the gases of the intestine, where it is liberated by fermentations.

Water forms about 70 per cent. of an adult human body. The proportion is greater in infants and less in the aged.

An adult takes in about 2500 c.c. and excretes about 2600 c.c. daily. The excess of 100 c.c. excreted, above that taken in, comes from the oxidation of the food or tissues. The proportion of water varies considerably in the various tissues and fluids of the body. The sweat contains 99.5 per cent.; the lymph, 93 to 96 per cent.; chyle, 90 to 97 per cent.; milk, 86 to 90 per cent.; blood, 78 per cent., as a mean; nerves, 70 per cent.; brain, 75 per cent.; muscles, 76 per cent.; cartilage, 55 per cent.; bones, 22 to 40 per cent.; teeth, 10 per cent.

Water is essential in carrying on the vital processes. It dissolves the substances intended for the nutrition of the tissues, as well as the waste products of their disintegration. It is thus the medium of all chemical reactions taking place within the body, and of the transfer of materials from one place to another. Water is one of the chief agents used by plants in building up the carbohydrates. It is also, in the animal, one of the chief agents used in the digestion, assimilation, and dissimilation of the proximate principles of foods. The water of the tissues may be diminished by hemorrhages, diarrhea, and other exhausting discharges. The person thus affected usually suffers intense thirst, and water should be supplied freely. It sometimes becomes necessary

(hemorrhage, cholera) to supply the water by venous injections of a 0.75 per cent. salt solution.

Frogs die when they have lost an amount of water equal to 30 per cent. of their body-weight; but they can live for two days in an atmosphere of pure oxygen, after all their blood has been displaced by a 0.75 per cent. salt solution. (Oertmann.) During this time they use the same amount of oxygen and exhale the same amount of CO_2 as in health. A considerable **increase of water** in the body is harmful, as it increases tissue-waste, dissolves hemoglobin from the red corpuscles, and thus reduces the oxygen-carrying power of the blood, and washes away the soluble saline matters. Injections of a great excess of water into the circulation may cause death.

A **deficiency of water,** if prolonged, leads to the accumulation of waste products in the blood and tissues, to deficient nutrition, often leading to constipation, dyspeptic symptoms, loss of weight, and rheumatic or gouty affections.

Hydrogen peroxide has been found in the sweat and a few other fluids of the body.

Hydrogen sulphide is found in the intestine as the result of the decomposition of bile and proteids by bacteria.

Ammonia is formed by the same decompositions, but it soon combines with acids to form salts.

Acids.—Free hydrochloric acid is found in the gastric juice.

Lactic acid occurs in the stomach during digestion, and it is produced in the intestine, along with butyric acid, by the action of special ferments. **Sarcolactic acid** is found in the juice of the muscles during and after active contraction. The acidity of muscle increases for some hours after death.

Metallic Salts.—Dissolved in the fluids or combined with the organic substances composing the tissues, are found certain metallic salts, which play an important rôle in nutrition. They give to these organic substances new and special properties, such as solubility, dialyzability; the power of solidifying, as in tendons and bones, and the property of elasticity, resistance, etc. Iron and copper play a specific rôle in the constitution of certain bodies (nuclein, protoplasm, hemoglobin, etc.).

Sodium chloride is the most abundant of these saline bodies. We absorb and eliminate about fifteen grams a day. Its principal function is to favor solution and osmosis of the proteid bodies, and it thus facilitates nutrition. It also facilitates the carrying away of the excrementitious matters formed by the activity of the cells. Common salt is necessary to the function of the various glands of the body. It enters into the composition of cartilage, bone, teeth, etc. A weak

solution of this salt increases the solubility of most of the proteids. It increases the urinary secretion without increasing the elimination of urea. About ten to fifteen grams of NaCl are excreted daily by the urine, besides that found in the perspiration, tears, and feces. Sodium chloride is more abundant than potassium chloride in the plasma of the fluids, while the latter is more abundant in the cellular elements.

Potassium chloride can not take the place of sodium chloride.

Potassium chloride is met with in the cells of every soft tissue, in the intercellular fluids, muscle-juice, and nervous tissue. It seems to have a true stimulant action upon the activity of the cells. Plants have need of and contain more potassium than sodium salts. This is probably because the principal work of plants is constructive, which action is stimulated by potassium salts. Sodium chloride rather favors the dissimilation of cell-waste. Herbivorous animals require some NaCl to favor a good state of health.

The **calcium salts** are furnished by both food and drink. Lime gives solidity to the skeleton and resistance to the whole body. It is the principal solidifying agent, and when the tissues degenerate it accumulates. In the disease called rickets and in osteomalacia it is deficient in the bones, which are soft and easily bent.

Magnesium is found in the tissues with lime. Its special rôle is not well understood. It is a constant ingredient in brain-matter, muscles, and the chlorophyll of plants.

The **sulphates** are always to be found in the urine and in other fluids. H_2SO_4 is constantly prepared by the disintegrated and oxidized proteids, most of which contain sulphur. About 70 per cent. of the sulphur of proteids of the food appears as sulphates in the urine. The sulphates of lime and magnesium are abundant in cartilage. We excrete by the urine from 1.5 to 2.5 gm. per day of sulphuric acid combined as sulphates and ethereal sulphates. They are increased by an animal and decreased by a vegetable diet.

The **alkaline carbonates** and **bicarbonates** exist in the lymph, chyle, saliva, bile, blood, etc. These salts of potassium exist in the blood and parotid saliva of herbivorous animals. It is the bicarbonate of sodium that gives most of the alkalinity to the blood and other liquids. With carnivorous animals the alkalinity is due to the phosphates and carbonates combined.

These salts are furnished by the food, especially as salts of the organic acids, which by oxidation are converted into carbonates. Both the absorption of oxygen and the oxidation of organic matters are favored by an alkaline medium. The bodies most easily oxidized in alkaline solutions are the sugars, alcohols, organic acids, and then

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fats; the last being first saponified, the glycerin and fatty acid being oxidized separately.

Ammonium carbonate is met with in traces in the blood. It appears in the blood, stools, and breath at the same time in cholera.

The **alkaline phosphates** are found in almost all tissues of the body. The phosphate of sodium, HNa_2PO_4, is the one to which the alkalinity of the blood is largely due. The potassium salt predominates in the blood-cells, and the sodium salt in the blood-plasma. The blood of omnivorous and carnivorous animals contains more phosphates than that of the herbivorous. The phosphates are eliminated principally by the urine in the form of neutral or acid phosphates of sodium, calcium, and magnesium. A little is excreted by the feces, and a small amount in some other forms.

As we take a large part of our phosphates in our food, as the potassium salt, it is probable that the sodium salt is formed by the reaction of NaCl upon K_2HPO_4 in the blood and lymph.

$$K_2HPO_4 + 2NaCl = Na_2HPO_4 + 2KCl.$$
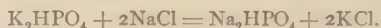
From this reaction there results the Na_2HPO_4 of the plasma and KCl of the corpuscles.

In all actively growing parts of the body, in red and white blood-corpuscles, in muscles, nerve-tissue, yolks of eggs, the seeds and young sprouts of plants, we usually find certain organic bodies rich in phosphorus, such as lecithin, nuclein, legumin, etc.

The **earthy phosphates** are met with in the bones, teeth, and in less amount in certain tissues and in the urine.

The **carbonate of calcium** is found to a slight extent in bones and in the shells of mollusks. It sometimes occurs in solution as the bicarbonate, but often in the insoluble state.

This salt sometimes gives rise to concretions in the saliva, or upon the teeth, and in the labyrinth of the ear (otoliths).

Silica occurs in small quantity in both plants and animals, but its function has not been clearly made out. It has some well-defined use, and is found very widely distributed in both animals and plants.

Iron is found as an essential constituent of certain coloring matters, as hemoglobin, yolk of egg, the pigments of the skin, hair, eyes, etc. The most remarkable compounds containing it are the hemoglobin of the red blood-corpuscles and the nuclein, or the nuclei of the cells throughout the body. One thousand parts of the blood of man contain 0.56 part of iron; of beef, 0.51; of the goat, 0.33 part.

Most of our food and drink contains traces of iron, and our meats

contain enough to satisfy our wants. It is eliminated by the bile and feces. Iron compounds seem to be the principal carriers of oxygen in the blood. We administer iron to increase the hemoglobin and the oxidizing power of the blood.

In vegetables, it enters into the composition of the protoplasm of cells, and possibly in the chlorophyll, although this is disputed. Iron seems to be essential to the growth of plants as well as of animals.

Copper enters into the composition of some plants and animals. As it always occurs in these organisms, it is safe to say that it has some unknown rôle to perform. In certain organisms it seems to replace iron. Copper is found to exist in many cereals and food-products. Lead, manganese, silver, zinc, and other metals are frequently taken with food or drink, and that they exert some action on the economy is certain, although we are ignorant of their exact function.

THE FERMENTS.

Very many of the changes that take place in the body are produced through the agency of **ferments.** Not only do we have to do with those soluble active proteids which produce hydrolysis of other compounds, breaking up complex molecules into simpler ones, but there are a number of such processes due to the action of certain microscopic organized bodies. It will be convenient, therefore, to give here some account of these ferments. They may be divided into two groups, the **soluble** and the **organized ferments.**

The **soluble** or **unorganized ferments,** or **enzymes,** are a class of albuminoid bodies which have the power, under favorable circumstances, of causing certain chemical changes in other bodies with which they are brought in contact, without themselves undergoing any change. They are called ferments because of the similarity of their action to that of yeast and other well-known ferments. Some of these bodies are of vegetable, while others are of animal origin. Those of vegetable origin are **diastase, emulsin, zymase, bromelin, papain,** and **myrosin;** while those of animal origin are **ptyalin** (salivary diastase), **pepsin, curdling ferment, pancreatic diastase, trypsin, invertin, histozym,** and probably others.

The exact chemical composition of these bodies is unknown, except that they are proteids. They are all soluble in water, are precipitated by alcohol and by lead acetate. They are not very diffusible, lose their activity by being boiled with water, but are not precipitated. They have not yet been obtained in a state of absolute purity. The artificial preparations are mixtures of the true ferment with other products

found with them in the digestive secretions. The soluble ferments are chiefly known under the collective name of **enzymes.** They are characterized by the fact that a very small quantity of the enzyme is capable of transforming a large amount of the substance acted upon. Their activity is dependent upon the temperature ; being absent at very low temperatures, increasing as the temperature is raised to a certain point, which varies slightly in different enzymes, then again diminishing as the temperature is further raised, and at a sufficiently high temperature they lose their activity, the proteid basis being coagulated and precipitated. They are generally sensitive to a change of reaction in the solution in which they are acting, from alkaline to acid, or from acid to alkaline. Certain salts destroy their action, while others only retard it. Their activity is in all cases lessened, and finally stopped, by the presence of an excess of the products to which they give rise. They will stand a higher temperature when dry than when in the moist condition. They may even be heated in the dry state to 100° C. (212° F.) without permanent loss of their activity. Analysis shows their composition to be more nearly that of the proteids than of any other class of substances. The basis of some of the enzymes appears to be a proteose, while others behave more like an albumin. The only means at our disposal for determining the presence of an enzyme is that of ascertaining the change it is able to produce in another substance.

The soluble ferments have a definite ascertainable limit of energy. Their power is used up in proportion to the work done, and the value of the ferment is generally estimated by determining the amount of food-substance which it can convert under fixed conditions. They are soluble in water, from which they are precipitated by an excess of absolute alcohol. In many cases they may be precipitated from their aqueous solution by saturation with $(NH_4)_2SO_4$. They are soluble in glycerin, from which they are precipitated by alcohol. They are not diffusible, and may be separated from diffusible substances by dialysis. They are prepared by cell-action in certain portions of plants and animals, but in most cases the enzymes do not exist in the free or active condition in the cells, but in the form of an inactive antecedent, to which the name of **zymogen** is applied. It is frequently necessary, therefore, to treat the tissue with some reagent that shall convert the zymogen into an active enzyme, in order to obtain an active extract. The solutions of the enzymes readily undergo fermentation and putrefaction, and lose their activity. It is essential, then, to insure the preservation of their activity in solutions, that some antiseptic be employed. The most suitable antiseptics for this purpose are chloroform (1 : 200), thymol (5 per cent.), salicylic acid (1 per cent.),

and alcohol (15 to 25 per cent.). In order to distinguish between the soluble enzymes and an organized ferment, it is best to carry on the digestion in the presence of chloroform, which is inert toward an enzyme, but inhibits the growth and activity of organized ferments. Sodium fluoride (1 per cent.) entirely checks the growth of the organized but is without action on the soluble ferments.

Diastase, or **maltin,** is the ferment formed from the gluten in the cereal grains at the time of sprouting. Malted barley contains at least three distinct enzymes. One of these acts upon cellulose, one upon starch, and one upon proteids. The first, or cellulose ferment, is sensitive to elevated temperatures, and to obtain it in an active state it is best to exhaust it from malt that has not been heated to a temperature above 35° to 40° C. At temperatures above 110° C. it begins to lose its activity, and at 130° to 140° C. it is rapidly killed. The starch diastase is more resistant to heat, but begins to lose its activity at and above 125° C. In the sprouting grain the cellulose-dissolving ferment is of service in dissolving the envelope of the starch grains. The chief object of diastase is the conversion of starch into dextrin and maltose. Ptyalin of saliva and pancreatic diastase, if not identical with vegetable diastase, act in exactly the same way for a time ; but the prolonged contact of these ferments changes the maltose, first formed, to glucose, while malt diastase does not. They all act upon cooked starch with great rapidity, but have a very slow action upon raw starch. The process is one of hydrolysis, and the action is similar to that which takes place when dilute sulphuric acid is boiled with starch or cellulose. When water is added to H_2SO_4, it probably forms H_6O_6S, $(H_2SO_4. 2H_2O)$ or ortho-sulphuric acid. This acid, when boiled, tends to part with a portion of its water, and if starch or other easily hydrated compound be present it imparts this water to that body, in the **nascent state,** so to speak. Diastase acts upon the starch at ordinary temperatures in the same way that H_6SO_6 does at a higher temperature. The first effect is to thoroughly liquefy the starch, then convert it into dextrin, and finally the dextrin into maltose. The most probable explanation of how the change is effected is that the enzyme combines with the starch to form a compound which reacts with water and splits up into two simpler compounds—the one a hydrate of the starch and the other the original enzyme itself.

Extracts of malt, as met with in the market, are infusions of malted barley, sometimes containing dextrin, malt-sugar, and dextrose. The bitter, non-saccharine " malt extracts " of the market, as a rule, contain little or no diastase, and are simply weak beers or infusions of malt.

A solid extract is now produced extensively by evaporating an infusion of malt, generally in a vacuum-pan, at a comparatively low temperature (110° F.). It should have a light color; the taste should be peculiarly sweet and the odor pleasant. The solution in nine parts of water should be only slightly turbid, and should give an abundant precipitate a few minutes after being mixed with an equal volume of picric acid. The insoluble matter should appear under the microscope as amorphous coagula and hexagonal prisms.*

The amount of starch that a given weight of diastase can transform is variously stated at from 2000 to 100,000 times its own weight, which, however, seems to be a fixed quantity with any given specimen of diastase. The rapidity of its action seems to depend upon the relative proportions of starch and ferment present. When the ferment is present in large quantity, the action is very rapid, almost instantaneous; while if it is small in proportion to the starch, it is slower in action. Diastasic ferment does not exist in the saliva and pancreatic juice of infants, previous to the sixth or seventh month, in sufficient quantity to digest much starch. The digestive power varies greatly in different infants.

The Diastasic Value of Malt Extracts and Pancreatic Extracts.—Roberts' method of determining the diastasic value of malt extracts and of pancreatic extracts is as follows: A 1 per cent. solution of starch-mucilage is employed. This is prepared by boiling 10 gm. of any pure starch in water, cooling, and making up to 1 liter. Ten c.c. of this standard mucilage are mixed in a beaker with 90 c.c. of water. The mixture is then warmed to about 40° C. (104° F.), and a measured amount of the malt extract or pancreatic extract is added, the exact time of adding it being noted. At short intervals a drop of the mixture is placed upon a plate or white slab with a drop of a diluted aqueous solution of iodine. As long as starch is present in the solution, it will continue to give a blue color. When all the starch is converted into erythrodextrin, a pink or brown color is produced. When all the erythrodextrin disappears from the solution no color is produced with iodine. This has been termed the **achromic point**. This point should be reached at the end of not less than six minutes, in order that the end reaction may be determined with sharpness. When prolonged beyond this time, the change is too gradual to be exactly determined. It is best, therefore, to take such an amount of malt extract or pancreatic extract that it will digest the 10 c.c. of starch-mucilage to the achromic point in from three to six minutes. For convenience of statement it is best to assume a standard time,—say, five minutes,—and calculate the amount of starch 1 gm. or other unit of the extract that will be digested in this time. Suppose, for example, it be found by experiment that 1 gm. of extract of pancreas, with 10 c.c. of starch-mucilage, reached the achromic point in three minutes. To calculate how much would be digested in five minutes, we form the proportion:

$$3 : 5 :: 10 \text{ c.c.} : \mathcal{C}$$
$$10 \times 5 = 50 \div 3 = 16.666 \text{ c.c.}$$

* Recently, a diastase of very high digestive power has been prepared by the action of a special ferment grown on wheat-bran. The diastase is afterward separated, by treating the bran with water and precipitating the solution with alcohol.

If in above test we had used 0.1 instead of 1 gm. of the extract, the activity must be ten times as strong as in the first case, and the ratio between the extract and starch would be 1 gm. to 100 c.c. instead of 1 gm. to 10 c.c.

This will be expressed in the following proportion:

$$3 : 5 :: \frac{10}{0.1} = \varphi. \quad \varphi = 5 \times \frac{10}{0.1} = \frac{50}{0.1} \div 3 = \frac{50}{0.3} = 166.66.$$

Or, we may simplify the statement thus:

$$\frac{10}{0.1} \times \frac{5}{3} = \varphi.$$

To reduce this to a general formula, let P represent the weight of extract taken, T the observed time, and D the diastasic value in the number of c.c. of starch-mucilage digested in five minutes by 1 gm. of extract: the formula then becomes—

$$D = \frac{10}{P} \times \frac{5}{T}.$$

To make the calculation in any given test, it is only necessary to substitute for P the weight or the volume of the diastasic solid or liquid under test, and for T the observed time in which the starch reached the achromic point, and work out the result.

Some prefer to multiply the final result of this calculation by 5 or 6, which will then represent the amount of starch digested in the stomach under normal conditions. When diastase is taken at the beginning of a meal, it acts in the stomach from twenty to thirty minutes before its action is stopped by the free hydrochloric acid. As the mucilage solution contains 1 per cent. of dry starch, the 166.6 c.c. of this solution contains 1.666 gm. This method is equally applicable to malt diastase, salivary diastase, or pancreatic diastase. A good dry extract of malt should digest its own weight of starch in twelve minutes.

Emulsin, or **synaptase,** occurs in sweet and bitter almonds. It may be extracted by digesting the almonds, freed from fat by pressure, for several hours, with water. The filtered liquid is acidified with acetic acid, to precipitate conglutin, and the emulsin is then thrown down with alcohol, filtered off, washed with alcohol, and dried. It is a white, friable mass, soluble in water, and capable of converting large quantities of amygdalin into sugar, prussic acid, and benzoic aldehyde; it also converts salicin into sugar and saligenin. Its aqueous solution readily decomposes, yielding lactic acid. A similar ferment has recently been found in certain parasitic plants, by which they are able to decompose glucosides found in the bark upon which they grow and feed upon them.

Myrosin is the ferment of mustard.

Pepsin (Br.), **pepsinum** (U. S. P.), contained in gastric juice, is secreted by the glands of the stomach. It may be separated from the other constituents of filtered gastric juice by dialysis, as it does not diffuse through membranes. It is readily prepared by digesting the mucous membrane of the pyloric end of the stomach of the pig, first

with strong alcohol, and after twenty-four hours expelling the alcohol by pressure, and digesting for some days with glycerin, slightly acidified with hydrochloric acid. It is filtered through muslin, then through paper, the pepsin precipitated with absolute alcohol, collected on a filter and dried. Other methods are in use.

Pepsin is a yellowish or grayish-white powder, soluble in water and glycerin, but insoluble in alcohol. It gives few of the albumin reactions, and is precipitated by the acetates of lead. When dry, it may be heated to 110° C. (230° F.) without losing its activity, but its solutions lose it at a much lower temperature. Its activity is greatest at about 40° C. (104° F.), and requires hydrochloric, phosphoric, lactic, or other diluted acid to develop its peculiar action. The presence of 0.1 per cent. of NaCl favors its action, but more than 0.5 per cent. hinders it. Admixture of bile, carbolic acid, or an excess of alcohol retard or entirely prevent its action. Nearly all metallic salts diminish the action of pepsin. Calomel is an exception to this rule, as are also arsenous and arsenic acids. Many of the alkaloidal salts have a retarding effect, but the chlorides have less than the sulphates. Sugar has a retarding action. Sodium salicylate, antipyrin, antifebrin, paraldehyde, and thallin, in small doses, stimulate the action of pepsin. Sodium carbonate quickly destroys it. The acid of gastric juice is mostly hydrochloric during the intervals of digestion, but during digestion several organic acids are set free by the hydrochloric acid from the acetates, malates, tartrates, etc., taken with the food, so that the real work of the digestion is accomplished with the aid of various organic acids instead of hydrochloric alone. The specific action of pepsin is the change of proteids, whether coagulated or not, into albumoses and peptones. Peptone is scarcely altered by putrefaction.

The proteolytic activity of pepsin varies greatly according to the process of manufacture, and the care exercised.

The U. S. P. requires that the official pepsin shall digest 3000 times its own weight of freshly coagulated and disintegrated egg-albumin in six hours, when tested by the method given.

Valuation of Pepsin.—The digestive value of pepsin is a matter of considerable importance. The method of the U. S. P. requires the following three solutions :

(a) To 294 c.c. of water, add 6 c.c. of diluted HCl.

(b) In 100 c.c. of solution **a**, dissolve 0.067 gm. (1 grain) of the pepsin to be tested.

(c) To 95 c.c. of solution **a**, brought to the temperature 40° C. (104° F.), add 5 c.c. of solution **b**.

Immerse and keep a fresh hen's egg for fifteen minutes in boiling

water. Then remove and place in cold water. When cold, separate the white coagulated albumin, and rub through a clean sieve having thirty meshes to the linear inch, rejecting the first portion passing through. Weigh off 10 gm. of the second clean portion, place in a flask of about 200 c.c. capacity, add half of solution **c**, and shake, to distribute the albumin evenly through the liquid. Then add the other half of solution **c**. Place the flask on a water-bath, and keep the temperature at about 40° C. (104° F.) for six hours, shaking gently every fifteen minutes. The albumin should have disappeared at the expiration of this time, leaving at most only a few, thin, insoluble flakes. The relative proteolytic power of pepsin stronger or weaker than that described above may be determined by ascertaining how much of solution **b** made up to 100 c.c. with solution **a** will be required to exactly dissolve 10 gm. of coagulated and disintegrated albumin under the conditions given above.

The above method is somewhat cumbersome and tedious, and there seems to be no fixed relation between the solution and digestion of the albumin. A better method is the following : Prepare two solutions :

No. 1.—To 25 gm. of the well-mixed whites of several eggs add enough distilled water to make exactly 250 c.c. Mix well, and boil the solution for five minutes. After cooling, make up the solution to the original volume with water. This solution contains 10 per cent. of egg-white, or about 1.22 gm. of dry albumin in 100 c.c.

No. 2.—One gm. of the pepsin to be tested is dissolved in 25 c.c. of water, 2 c.c. of diluted HCl (U. S. P.) is added, and enough water to make the solution up to 50 c.c.

Procedure.—Measure out into a beaker or bottle 50 c.c. of the albumin solution and warm on a water-bath to about 40° C. (104° F.). Add to this 2 c.c. of diluted HCl (U. S. P.), and from 0.5 to 5 c.c. of the pepsin solution. The more active the pepsin, the less the quantity to be taken. It will sometimes be necessary, with an unknown pepsin, to make a preliminary test to determine the approximate time required by the digestion, as it is best to so regulate the quantity of pepsin and albumin that the digestion may be complete in a little less than two hours. The time when the pepsin is added must be carefully noted, and the temperature kept at about 35° to 40° C. (95° to 104° F.). At intervals of ten minutes draw out a few drops of the solution with an ordinary dropper pipette, and float it upon a few drops of pure HNO$_3$ in a narrow test-tube. Note the time when the HNO$_3$ ceases to give a coagulum of albumin, or when the albumin disappears. We next assume the standard time of three hours, the average time of stomach digestion. The relation between the quantities of albumin and pepsin is found by dividing the amount of albumin by the weight of the pepsin. This should be so regulated that the digestion is complete between two and three hours, in order to be comparable with the U. S. P. method. Fifty c.c. of the above albumin solution will contain 5 gm. of egg-white, 0.5 c.c. of the pepsin solution will contain 0.01 gm., and 5 c.c. will contain 0.1 gm. of pepsin. The ratio of pepsin to egg-white will then be 1 : 500 and 1 : 50, respectively. Egg-white contains about 12.2 per cent. of dry albumin, but it varies considerably in different eggs—from 10 to 14 per cent. This method gives an exact statement of results, requires little if any skill in manipulation, and requires no shaking. The results are uniform when the time is about from two to three hours.

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Trypsin occurs in the pancreatic juice, and may be extracted, along with the other enzymes, from the pancreas by a process similar to that described above for pepsin, except that no acid is used. Thus prepared, **pancreatin, pancreatum** (U. S. P.), is a yellowish-white, amorphous powder, soluble in water and glycerin, but precipitated by alcohol. It possesses the property of acting upon the proteids in a way somewhat similar to pepsin, but is active only in alkaline solutions. The pancreatic juice, the liver, and the blood-serum contain a ferment called **steapsin** or **pialyn,*** which is not soluble in glycerin, and is destroyed by acids and alcohol. It emulsifies and partially saponifies the fats.

A part of the peptone at first formed by the pancreatic juice is afterward converted into tyrosin, leucin, aspartic acid, and tryptophan. The digestion of the proteids is thus begun in the stomach, in an acid medium, and finished in the small intestine, in an alkaline medium. There is this difference in the two processes : that while acid pepsin readily liquefies the proteid bodies, it does not completely convert them into peptones ; this completion of the process is more quickly and completely done by the trypsin. (See under Albumoses.) The secretion of Peyer's glands converts dextrin and maltose into dextrose, but does not affect starch.

The diastase of the pancreatic juice, also called **amylopsin,** is identical in its action with the **ptyalin** of the saliva and with malt-diastase, already described. Like these, it converts starch into maltose, but it acts better in the presence of bile than when alone. The method of determining the diastasic value of pancreatic extracts is the same as that described above for malt extracts.

Rennin, or milk-curdling ferment, is found in the extract of the pancreas. It is not so abundant in this gland, however, as in aqueous and glycerin extracts of the mucous membrane of the stomach.

Nothing is known of the chemical nature of rennin. Under the name of **rennet** it has been employed for centuries to coagulate the caseinogen of milk in the manufacture of cheese. For this purpose it is usually prepared from the stomach of the calf, where it exists, in the form of **rennen zymogen,** which is converted by standing or by weak acids into rennin. It occurs in the stomachs of both children and adults. It has been found in small quantities in normal urine.

Fibrin-ferment.—The coagulation of paraglobulin in the formation of blood-clot is now believed to be caused by a special ferment.

It may be prepared by mixing blood-serum with ten to fifteen volumes of strong alcohol, allowing it to stand fourteen days, and filtering. The precipitate contains coagulated proteids with the

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* Also sometimes called **lipase.**

ferment adhering to them. The ferment may be dissolved out by water. The blood in circulation does not contain the ferment, but it is formed by some change after the blood is drawn from the vessels ; probably by the disintegration of the white corpuscles and the third corpuscles. or blood-plates. It seems to be a globulin-like body. There are other globulins which have a similar action in the formation of fibrin to that of this ferment. The **myosin** of muscle-juice is especially to be mentioned as one of them. This is sometimes described as **muscle-enzyme.**

Invertin, or **invertase**, is a ferment existing in the intestinal juice, which has the power of inverting cane-sugar—*i. e.*, it converts it into dextrose and levulose. Of its composition and other properties little is known. **Invertin**, or a substance possessing the same property, as well as a diastasic ferment, is found in the liquid portion of bakers' or brewers' yeast, after the cells have been killed by alcohol. While alive, the cells do not impart the invertin to the solution. Invertin does not affect lactose, maltose, starch, or gums.

Zymase is a soluble ferment that has been separated from yeast by pressure. Its solutions cause the alcoholic fermentation of cane-sugar and grape-sugar without the presence of yeast-cells. Lactose is not affected by it.

Histozym is a soluble ferment, supposed to exist in the blood, liver, and kidneys, and which has the power of causing a variety of reactions within the body, such as the conversion of benzoic into hippuric acid, etc.

Some authors have described certain other ferments under the name of **microzimas,** which act as active chemical and physiological agents in the body during life, and cause its decomposition after death. They appear as minute molecular granules, and are regarded as a part of the living organism by some, and as distinct organized ferments by others. As these molecular granules do not seem to undergo reproduction, and are not destroyed by antiseptics, it seems unlikely that they are organized structures.

Papain is a ferment prepared from the milky juice of the papaw tree. It is a white, amorphous, granular powder. It is soluble in water and glycerin. This ferment peptonizes proteids very rapidly, the end product being leucin, and coagulates milk. It acts like trypsin. It has been used to digest the membrane of croup and diphtheria. Hydrochloric acid lessens its action, as does carbolic acid, but they do not arrest it. It can act in an alkaline, neutral, or feebly acid solution. Under the name of **papoid** it is found in the market as a remarkably active digestive agent. It resembles in its action the trypsin of pancreatic fluid.

Bromelin is the name given to a proteolytic ferment of pineapple juice.

It appears to be associated with a peculiar, proteose-like substance. It acts upon fibrin, albumin, and myosin to produce proteoses. It does not seem to produce peptone.

Similar proteolytic ferments have been found in the juice of the fig-tree, in the fruit of *Cucumis utilissimus*, a plant found in India, and in certain seedlings, as barley, poppy, maize, wheat, rye, etc.

ORGANIZED FERMENTS.

Somewhat similar in action to the preceding group of ferments are certain forms of low vegetable organisms, which are known as **organized ferments.** These organisms vegetate most readily at temperatures of from 20° C. (68° F.) to about 40° C. (104° F.). Temperatures above or below these limits retard their growth, while a temperature near the boiling point entirely destroys their activity. A very minute quantity of any of these ferments can grow and exert its peculiar action as long as its peculiar nourishment lasts and proper conditions of its life are maintained. Organized ferments excite chemical changes, as the direct physiological result of their growth. They are all killed by hydrogen peroxide, and the chemical change is stopped by it. All physiological fermentations in the organism are caused by the soluble ferments, while pathological fermentations are caused by the organized ferments. The **antiseptic** agents are, as a rule, **antifermentatives**, and check the growth of and in many cases kill the organized ferments. (See p. 171.) The changes produced by the enzymes may be distinguished from those produced by organized ferments by the addition of chloroform or sodium fluoride (one per cent.), both of which check the growth of organized ferments, while the action of enzymes is not interfered with.

The most important of the ferments of this class are yeast, or alco-holic ferment, acetic acid ferment, and lactic, butyric, nitrifying and putrefactive ferments. With the exception of the first of these or-ganisms, they all belong to the bacteria family.

Yeast (**torula**, or **Saccharomyces cerevisiæ**) consists of one-celled, globular or oval-shaped, microscopic plants, multiplying by budding. There are several varieties of this fungus. The princi-pal action caused by yeast in saccharine fluids is, first, to convert the saccharose into invert-sugar, and then change this into alcohol, carbon

dioxide, and a trace of succinic acid and glycerin. The spores of yeast are always to be found either in the air or upon the surface of fruit, whence they find their way into the solutions made from their juices, which explains the apparent spontaneous fermentation. Invertin accompanies the growth of yeast. It has the power of inverting cane-sugar. (See p. 555.)

Acetic acid ferment (**Mycoderma aceti**) occurs usually in the form of chains of very small, globular bodies, formed by the multiplication of the cells by divisions, at right angles to the line of growth. It belongs to the bacteria family. It grows in alcoholic solutions containing a small amount of albuminous matter or ammoniacal salts, and alkaline and earthy phosphates. A little acetic acid favors its growth, as well as a free supply of air. It acts by causing an oxidation of the alcohol to acetic acid; when this change is complete, the ferment dies for want of nourishment.

Saccharomyces albicans (**Oidum albicans**) is the ferment which is found growing upon the mucous membrane of the mouth of infants, producing the disease known as "thrush" or "sprue." The fungus appears as white patches upon the tongue and other parts of the mouth. The cells are globular, oval, or cylindrical, and occur in colonies or rows. It excites alcoholic fermentation.

Lactic and **butyric** fermentations go hand in hand, the former usually, if not always, preceding the latter. They thrive best in a neutral or alkaline medium, and grow best without oxygen, at a temperature of 35° C. to 40° C. (95° F. to 104° F.). These conditions exist in the intestines, and they are always found there. The substances most prone to these fermentations are sugars, organic acids, soluble proteids, and especially mucus. The products of the fermentation are lactic, acetic, and butyric acids, carbon dioxide, and free hydrogen. These gases distend the bowel and often produce colic. Any excessive production of mucus in the bowel greatly favors these fermentations.

The growth of the **Bacillus butylicus** furnishes a soluble ferment which has the power of inverting cane-sugar and slowly peptonizing proteid, but it does not hydrolize either lactose or starch.

Urea-ferment.— When urine is exposed to the air, its acidity at first increases, and then diminishes rapidly, and gives way to an alkaline reaction. The solution is then found to contain ammonium carbonate, formed from the urea. This is due to a hydrolytic change resulting from the growth of certain micro-organisms, of which the best known is the **Micrococcus ureæ.**

Recent investigations seem to prove that these organisms are not the only agency that brings about this change, but that there is prob-

ably a soluble enzyme that assists them, or may even perform the conversion without the presence of the organisms.

It is quite certain that the mucus secreted in catarrh of the bladder can produce the change, as it takes place in the presence of chloroform and of sodium fluoride. If a urine which is full of urea ferment be filtered through a filter that allows no organisms to pass, the change is stopped. If it be treated with alcohol before filtering, the filtrate has the power of producing the change. It thus seems that the alcohol extracts an enzyme from the organisms, while water does not. The most prolific source of this enzyme is the mucus of cystitis.

Putrefactive fermentation is caused by the growth of various forms of bacteria. The proteids are most liable to putrid fermentation. This fermentation takes place in all organic infusions containing proteid matters, when exposed to the air; it also occurs in the small intestine, in cases of constipation, or in some forms of indigestion, and to a slight extent in the normal conditions. The putrefactive ferments are classified into **aerobic** (those requiring oxygen) and **anaerobic.** The first give a little gas, little or no ammonia, and a putrid odor. The second class decompose the proteid matters, producing at first hydrogen, and a little carbonic, acetic, lactic, and butyric acids. Then the matter becomes strongly alkaline from the production of ammonia, with escape of nitrogen, ammonia, hydric sulphide, and complex phosphorous compounds. At the end of some days the mass gives off almost pure CO_2 and NH_3, and there goes into solution a series of amins and amids, among which are leucin, tyrosin, and amidostearic, caproic, butyric, and palmitic acids. The two last predominate. At the same time phenol, skatol, indol, pyrrhol, and phenyl-acetic, phenyl-propionic, oxyphenyl-propionic, skatol-carbonic, and skatol-acetic acids make their appearance. Finally, more or less poisonous toxalbumins, peptone, and ptomaines appear. These products do not all appear in all cases, but are modified by the substance acted upon, and by other conditions.

Nitrifying Ferment.—This ferment consists of certain microorganisms found in all soils containing organic matter, and found especially abundant about the rootlets of plants. They are also found in surface-waters. Their function is to convert albuminoid matters and ammonia into nitrous and nitric acids. They therefore act as oxidizing agents, similar to the acetic ferment. It is by this agency that polluted waters dispose of their nitrogenous organic matter, and purify themselves.

When a water has thus purified itself, the nitrogen will be found in the form of nitrates or nitrites of the metals. (See p. 146.)

It is by the aid of these organisms that plants are able to feed upon albuminoid matters in the soil, fix the free nitrogen of the air, and make a plant food of it.

Disease-producing Organisms.—The organisms of the contagious and infectious diseases belong in this class of organized ferments. They are believed to owe their peculiar action on the body to the peculiar toxins which they produce while multiplying in the fluids. In many cases it has been proven that the toxins which the microbes secrete, and which are precipitable with alcohol, are the active agents. When injected into the circulation, they produce, with or without fever, a state of resistance to the growth of the microbe or its effects, called immunity. (See Toxins.)

NUTRITION.

As has already been stated, animals derive their nourishment from the vegetable kingdom, either directly, or they live upon animals who, in turn, live upon a vegetable diet. Foods are substances which are required for the nutrition of the body. It has been calculated that the average adult man loses about 1000 gm. of solid matter daily in the expired air, sweat, urine, feces, and other excretions. Food is necessary to replace this waste, if the body-weight is to remain constant.

Nutrition takes place in five different phases—viz., digestion, absorption, assimilation, destructive metabolism, and elimination of waste, or excretion. **Digestion** is the process of converting food into dialyzable compounds. Digestion is followed by **absorption**; that is, the passage of the products of digestion through the walls of the alimentary canal into the blood and lymph, which carry the absorbed material to the tissues. The tissues take up the digested and absorbed material for the nutrition of their cells. This is called **assimilation.** In some cases assimilation is delayed by the storing up of materials for future use, such as the storing of glycogen in the liver and of fat in the connective tissue. **Destructive metabolism** is the process continually going on in the tissues, by which they are disintegrated during the physiological activity of the cells. The oxygen is supplied by respiration, and the energy of this oxidation is used up in the physiological activity of the tissues and the production of heat. By this process stored energy is converted into muscular or nerve energy. It consists at first in a cleavage of the complex protoplasmic molecules into simpler molecules. These cleavage products are generally soluble and diffusible ; they are passed to the periphery of the cells,

and here the process of oxidation begins. It is yet a disputed point whether any portion of the food is oxidized without first being assimilated. The **elimination of waste products** is the discharge from the system of the products of the destructive metabolism. These waste products are no longer required in the system, as their energy has been used up.

FOODS AND DIET.

Foods are mixtures of various inorganic and organic materials, which are usually termed **proximate principles.** The chief proximate principles of food are the same as the chief proximate principles of the body. They may be classified as follows : Water, metallic salts, proteids, gelatinoids, fats, carbohydrates, and a few other less important organic constituents. These proximate principles do not occur in natural foods in the pure state, but are mixed in varying proportions. It is necessary, in a suitable diet for man, that all these above-mentioned proximate principles should exist ; and hence, we find them mixed for use in natural foods. In milk and eggs, for example, which form the exclusive food-stuff for young animals, we find all the proximate principles mixed in suitable proportions ; hence, they are frequently spoken of as **perfect foods.** Eggs, although a perfect food for the chick, are not quite perfect for mammals, as they contain too little carbohydrate. In vegetable foods, as a rule, the carbohydrates predominate, and are, therefore, necessarily mixed with fat and nitrogenous substances in the form of animal food.

Diet.—A healthy and suitable diet must possess the following characteristics : (1) It must contain the proper amount and proportions of the various proximate principles ; that is, of proteids, fats, carbohydrates, salts, and water. (2) It must be adapted to the age, sex, and habits of the individual, and to the climate. (3) It must not only contain the proper proximate principles, but they must be in a digestible form. (4) The object of food being to nourish the tissues and repair the loss due to destructive metabolism, the relation between food, exercise, and excretion must be properly regulated.

In the consideration of diet, it is usual to consider chiefly the three proximate principles—carbohydrates, proteids, and fats. It is necessary that these three ingredients should be adjusted so that neither should be in great excess over and above the needs of the body. The proportion of carbon to nitrogen in proteids is about as 15 to 35, or 1 to 3.5. If a person live entirely on proteid food, his diet will con-

tain too much nitrogen and too little carbon. If he live entirely upon carbohydrates, he would not get sufficient nitrogen to nourish the tissues. The fats and carbohydrates, taken together, are sometimes called the non-nitrogenous foods. In carbohydrates the H and O exist in the proportion to form water. We may regard the H, therefore, as completely burned in these substances, and not available for combustion or the generation of energy, the carbon alone being available for this purpose. Fats contain much less O in proportion to their carbon and H than do the carbohydrates ; they, therefore, generate more heat in their complete oxidation than the latter. The following reactions will serve to make this clear :

$$C_{12}H_{22}O_{11} + 12O_2 = 11H_2O + 12CO_2$$
$$\text{Sucrose.}$$
$$C_3H_5(C_{18}H_{33}O_2)_3 + 77O_2 = 57CO_2 + 52H_2O.$$
$$\text{Triolein.}$$
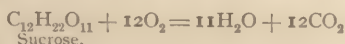
It is found that animals thrive best on diets which supply them with the bulk of their carbon from both fats and carbohydrates. The diet which man constructed for himself, long before theories explained why he did so, contained both carbohydrates and fats. Again, the foods which nature has provided for growing animals, in the form of milk and eggs, contain fat, carbohydrates, and proteids. From this it would be inferred that all three of these constituents are essential to the proper nourishment and growth of animals.

Dynamic Energy of Foods.—Heat and muscular power, or dynamic energy, is one of the important offices of all food. The final result of the chemical changes going on in the body, sometimes termed metabolism, is chiefly an oxidation process. The oxidation of organic matter always develops more or less heat energy. Heat and muscular power are convertible in the body, and articles that produce heat produce also muscular energy. The consideration of the dynamic energy of foods is based upon the following principles of thermochemistry :

1. The quantity of heat evolved in any reaction may be taken as a measure of the chemical and physical work accomplished.

2. When a series of reactions take place in a number of bodies, the amount of heat absorbed or evolved will depend solely upon the initial and final state of the bodies concerned in the reactions, without regard to the intermediate changes or conditions through which they pass.

3. In any chemical reaction between a series of bodies not acted upon by external forces, the tendency is toward that condition which will result in the production of the greatest amount of heat.

In the application of these principles to the action of food in the animal body, two factors are to be determined :

1st. The heat evolved by the various food-materials when burned outside of the body.

2d. The heat evolved by these same foods when burned in the body.

The first is determined by burning a known weight of the food in a calorimeter. The second is determined by feeding experiments with man or one of the lower animals, so conducted as to measure the food and air given, the amount stored in the body, all the waste material excreted, the heat evolved, and the muscular and nervous energy expended.

This is done by putting the man or animal under experiment in a larger calorimeter, usually called a respiration calorimeter.

As heat and mechanical work are mutually convertible, energy is usually reckoned either in terms of work done or as its equivalents in heat units. The unit of work is the foot-pound or foot-ton in English measure, or the gram-meter or kilogram-meter in the metric system. The heat unit, or calorie, is the amount of heat necessary to raise the temperature of 1 kilogram of water from zero to 1° C. In English measures a thermal unit is the amount of heat necessary to raise 1 pound of water from zero to 1° C.*

A thermal unit = 0.45 calorie.
A calorie = 2.2 thermal units.
A thermal unit = 1390 foot-pounds, or 0.695 foot-ton.
A calorie = 425.5 kilogram-meters, or 425,500 gram-meters.
A calorie = 3077.6 foot-pounds.
1 Kilogram-meter = 7.233 foot-pounds.
1 Foot-pound = 0.138 kilogram-meter.

The heat of combustion is the same, whether the food be burnt in the air or in the human body. The apparatus which is employed for determining the heat of combustion of bodies (Fig. 63) consists of a vessel surrounded by a known weight of water, and in which the substance is burned with oxygen. The heat is communicated to the surrounding water, and the rise of temperature of the water is carefully measured with a thermometer. It is called a calorimeter. The substance to be burned is placed in the combustion-chamber, K. This chamber is suspended in the larger vessel, L, filled with water, which completely surrounds the combustion chamber. The vessel containing the water is surrounded by a layer of non-conducting material, M, and

* A thermal unit is sometimes taken as the heat necessary to raise 1 pound of water 1° F. A smaller calorie is also sometimes used, which is the heat required to raise 1 gm. of water 1° C.

then put inside of a larger vessel containing water. The combustion chamber has three tubes passing into it : O supplies air to support the combustion; a is an observation tube ; d is used to conduct gases when these are to be burned, and g leads out the gases produced by the combustion, and is made to traverse the water through a long distance, so as to cool the gases thoroughly. A weighed quantity of the substance can be burned in the calorimeter, and the heat produced
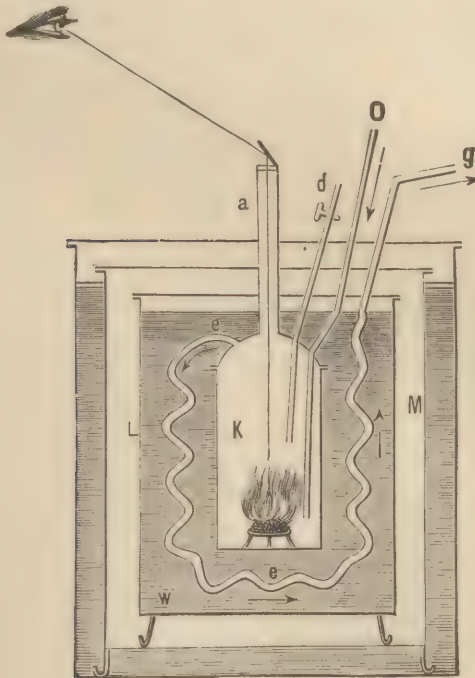
FIG. 63

is estimated by noting, by a delicate thermometer, the number of degrees in temperature the known weight of water in the instrument is raised.

The degrees of rise in temperature of the water, multiplied by the weight of the water in kilograms, gives the number of calories produced in the burning of that amount of the food taken for the experiment.

The following proximate principles, when burned, give the following amounts of heat and work:

	CALORIES.		FOOT-TONS.	KILOGRAM-METERS.
	Per Gram.	Per Ounce.		
Proteid, ... 4.2		116.26	6.4	1787
Fat, ... 9.3		263.70	14.2	3957
Carbohydrate, . . 4.1		116.25	6.3	1744

Dr. Rubner obtained, by comparative feeding experiments upon animals, and with the calorimeter, the following figures. Taking the thermotic value of fat at 100, he found that to give the same amount of heat it required of—

	BY FEEDING EXPERIMENTS.	BY CALORIMETER.
Myosin, ...	225 parts.	213 parts.
Lean meat, ...	243 "	235 "
Starch, ...	232 "	229 "
Cane-sugar, ...	234 "	235 "
Grape-sugar, ...	256 "	255 "

That is, 1 gm. of fat gives the same amount of heat as 2.25 gm. of myosin, or as 2.56 of grape-sugar. From these or similar experiments, it is possible to arrive at a definite estimation of the potential energy produced by foods. It has been found that the heat value of proteids, when burned in the body, is equal to that of carbohydrates, and is, therefore, a little less than one-half the value of fat, as a heat-producing agent. It must be remembered, however, that there is this difference: that lean meat has for one of its chief offices the building-up of tissue and repairing waste. We do not, therefore, obtain all the possible heat and muscular power from it, as we do from the carbohydrates and fats. About one-third of its heating power remains in the urea which is formed from it. In accurate experiments in feeding the human body, it has been found that the proteids, fats, and carbohydrates replace one another in almost the exact proportion of their heats of combustion, when the person experimented with is in a state of idleness. The following table, arranged by Frankland, gives the force produced by 1 gm. of the common articles of food:

Food.	Percentage of Water.	Force-producing Value.		
		In Calories.	In Kilogram-meters.	
			When Burnt in Oxygen.	When Burnt in the Body.
Cod-liver oil, ...	. . .	9.107	3857	3857
Beef fat, ...	. . .	9.069	3841	3841
Butter, ...	. . .	7.264	3077	3077
Cheshire cheese, ...	24.0	4.647	1969	1846
Oatmeal, ...	. . .	4.004	1696	1665
Flour, ...	. . .	3.936	1669	1627
Pea-meal, ...	. . .	3.936	1667	1598
Arrowroot, ...	. . .	3.912	1657	1657
Ground rice, ...	. . .	3.813	1615	1591
Yolk of egg, ...	47.0	3.423	1449	1400
Cane-sugar, ...	. . .	3.348	1418	1418
Hard-boiled egg, ...	62.3	2.383	1009	966
Bread crumb, ...	44.0	2.231	945	910
Mackerel, ...	70.5	1.789	758	683
Lean beef, ...	70.5	1.567	664	604
Potatoes, ...	73.0	1.013	429	422
Whiting, ...	80.0	0.904	383	325
White of egg, ...	86.3	0.671	284	244
Milk, ...	87.0	0.662	280	266
Apples, ...	82.0	0.660	280	273
Cabbage, ...	88.5	0.434	184	178

The following table gives the calorific value of 100 gm. and of 1 oz. avoirdupois, and will be found useful in calculating dietaries :

Calorific Value of 100 Gm. and 1 Oz. of Some Standard Foods (Jürgensen).

	Calories.	
	Per 100 Gm.	Per Oz.
Whole milk, ...	67.5	19.3
Skim milk, ...	39.61	11.3
Cream, ...	214.7	61.34
Buttermilk, ...	41.56	11.8
One egg, ...	80.0	22.9
Buttered egg, ...	187.6	53.6
Wheat-bread, ...	281.0	80.0
Wheat-bread (toasted), ...	258.8	74.0
Zwieback (wheat), ...	357.8	100.2
English biscuit, ...	419.9	119.9
Cakes, ...	374.0	107.0
Butter, ...	814.0	231.0

CALORIFIC VALUE OF 100 GM. AND 1 OZ. OF SOME STANDARD
FOODS (Jürgensen).—(*Continued.*)

	CALORIES.	
	Per 100 Gm.	Per Oz.
Beef (raw), ...	118.95	33.5
Beef (broiled), ...	213.6	61.1
Beef (boiled), ...	209.0	60.0
Veal-cutlets (raw), ...	142.45	40.7
Veal-cutlets (broiled), ...	230.5	65.9
Chicken-breast (raw), ...	106.4	30.4
Pigeon (raw), ...	99.7	28.48
Calf-brains (raw), ...	140.0	40.0
Carp (raw), ...	93.0	26.57
Flounder, ...	100.6	28.74
Salmon, ...	133.3	35.23
Sole, ...	95.2	27.2
Trout, ...	106.4	30.4
Potato-bread (with butter), ...	127.4	36.4
Spinach, ...	165.65	47.33
Carrots, ...	41.0	11.7
Bean-soup, ...	193.0	55.14
Green peas, ...	318.0	62.3
Asparagus, ...	18.5	5.5
Oatmeal, ...	288.5	82.4
Macaroni, ...	352.6	100.7
Omelet, ...	236.7	67.62

The calorific value of any food may be calculated from its proximate composition by multiplying the percentage of proteid, fat, and carbohydrate by the amount of heat developed by 1 gm. or 1 oz. of each, and adding together these products. As percentage represents parts in 100, the above calculation will give the heat to be obtained from 100 gm. or 100 oz., according as the factors for 1 gm. or 1 oz. is used in the calculation.

Diet Tables.—The proper construction of the diet for man has been made the subject of a great deal of investigation, and is a matter of considerable importance. The attempt has been made in various ways to determine the necessary daily diet of a man under different conditions. The following table shows the estimates of the ten observers whose names appear at the top of the table :

TABLE GIVING THE STANDARDS OF DIET, AS DETERMINED BY DIFFERENT INVESTIGATORS. (ADULT MAN, DOING LIGHT WORK.)

	Moleschott		Pettenkofer and Voit		Ranke		Playfair		Foster		Landois		Dujardin-Beaumetz		Rubner		Munk		Atwater		Average	
	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.
Proteids,	130	4.6	137	4.8	100	3.5	119	4.2	133	4.7	120	4.2	124	4.4	127	4.4	100	3.5	125	4.4	121.5	4.3
Fats,	84	3.0	117	4.1	100	3.5	51	1.8	95	3.2	90	3.2	55	1.9	52	1.8	56	2.0	125	4.4	82.5	2.9
Carbohydrates,	404	14.2	352	12.4	240	8.5	530	18.7	422	15.0	330	11.6	430	15.1	509	18.0	400	14.1	450	15.8	406.7	14.4
Salts,	30	1.1	30	1.1	25	0.9																
Total dry food,	648	22.9	636	22.4	465	16.4	700	24.7	650	22.9	540	19.0	609	21.4	688	24.3	556	19.6	700	24.6	610.7	21.6

It will be seen that there are considerable differences in the estimates of different authors. Less variation is observed in the amount of proteids than in the fats and carbohydrates. The results are given in grams and in avoirdupois ounces. The last column gives the average of the ten authors quoted.

The following table gives the amount of a number of the common foods which will contain the average daily needs of the human body, according to Moleschott's estimates :

	WEIGHT OF FOOD WHICH CONTAINS	
FOOD.	120 gm. of proteid.	420 gm. of non-proteid (90 of fat, 330 of carbohydrates).
Cheese, ...	350 gm.	1530 gm.
Lentils, ...	453 "	693 "
Peas, ...	537 "	704 "
Beef, ...	566 "	1945 "
Hens' eggs, ...	893 "	776 "
Wheat-bread, ...	1332 "	543 "
Maize, ...	1515 "	643 "
Potatoes, ...	6000 "	1751 "

The following table gives the results arrived at by different investigators, as to the necessary daily amounts of the three proximate principles demanded by adults in different conditions, with the calories generated by these quantities. To convert this last column into the equivalent in work it is only necessary to multiply the number of calories by 3077 to reduce it to foot-pounds, or by 1.539 to get foot-tons. The weights of the nutrients are given in grams :

EUROPEAN DIETARIES.

	PRO-TEIDS.	FAT.	CARBO-HYD'TE.	CALOR-IES.	AUTHOR.
Soldier in peace, ...	119	40	529	2784	Playfair.
" in light service, . . .	117	35	447	2424	Hildesheim.
" in the field, ...	146	44	504	2852	"
Laborer, ...	130	40	550	2903	Moleschott.
" in idleness, ...	137	72	352	2458	Pettenkofer and Voit.
Carpenter (40 years), ...	131	68	494	2835	Forster.
Young physician, ...	127	89	362	2602	"
" "	134	102	292	2476	"
Laborer, servant, ...	133	95	422	2902	"
English smith, ...	176	71	666	3780	Playfair.
" prize-fighter, ...	288	88	93	2189	"
Wood-chopper (Bavarian), . .	135	208	876	5589	Liebig.
Laborer (Silesian), ...	80	16	552	2518	Meinert.
Seamstress (London), ...	54	29	292	1688	Playfair.
Soldier in peace, ...	130	40	551	2900	Hammersten.
" in war, ...	146	59	557	3250	"
Average population (Paris), .	115	48	333	2219	Gautier.

AMERICAN DIETARIES (Expressed in Pounds Avoirdupois).

	PRO-TEIDS.	FAT.	CARBO-HYD'TE.	CALOR-IES.	AUTHOR.
Family of carpenters, ...	0.25	0.28	0.76	3.055	Atwater.
" glass-blowers, . . .	0.23	0.29	1.06	3.590	"
Operatives in cotton-mills, . .	0.29	0.44	1.21	4.650	"
Well-paid machinists, ...	0.23	0.44	0.84	3.490	"
Average of 20 dietaries of wage-earners (Mass. and Conn.), .	0.34	0.50	1.38	5.275	"
Average of 5 dietaries of college students and professional men (Middletown, Conn.), .	0.27	0.34	1.08	3.925	"
Brickmakers, at hard work, . .	0.40	0.81	2.54	8.850	"
Standard dietary in Mass. and Conn. with moderate work, .	0.28	0.28	0.99	3.520	"
Standard for hard muscular work, ...	0.39	0.55	1.43	5.700	"

Taking the figures in the last column, rejecting those which are exceptionally high or low, we find that the average European dietaries give about 2800 calories, and the average American dietaries give about 3500 calories. The amount of nutrients required for children is greater in proportion to their body-weight than for adults. The following table gives the nutrients needed for children at various ages :

AGE OF CHILD.	WEIGHT IN POUNDS.		PROTEIDS.		FAT.		CARBO-HYDRATES.		CALOR-IES.
	Kilos.	lbs.	Gm.	Oz.	Gm.	Oz.	Gm.	Oz.	
Sixth day (girl), . .	2.5	5.5	7	0.25	11	0.4	15	0.53	192.5
End of second week, .	2.8	6	12	0.42	20	0.67	27	1	346
Four months (boy), .	4.5	10	19	0.66	29	1	41	1.41	516
1½ years (girl), . . .	9	20	40	1.4	36	1.27	80	2.8	827
3 years (girl), ...	12.6	28	43	1.5	39	1.4	189	6.66	1314
4 years (boy), . . .	17.4	37.3	61	2.15	43.5	1.53	191	6.7	1438
6 years (boy), . . .	18	39.6	63	2.2	45	1.6	198	6.9	1489
8–9 years, ...	. .	. .	60	2.1	44	1.5	150	5.3	1270
12–13 years, ...	. .	. .	72	2.5	47	1.6	245	8.6	1808
14–15 years, ...	. .	. .	79	2.8	48	1.7	270	9.5	1877

Calculation of Daily Dietaries.—From the data above given it is an easy matter to arrange a mixture of foods to give the necessary daily energy demanded by persons in any desired condition.

This is an important matter to the physician, as he is frequently called upon to arrange dietaries for prisons, asylums, soldiers, and other collec-
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tions of individuals. It is frequently desirable to prepare a dietary for the purpose of increasing or diminishing flesh, or in the treatment of certain diathetic diseases. We will give an example of the method of calculating a diet table to consist of beef, bread, butter, oatmeal, and potatoes, and to furnish approximately 3500 calories of heat.

Beef (weighed raw),	. . . .	14 oz.	= 469 calories.
Wheat-bread,	. . . .	20 "	1800 "
Butter,	. . . .	3 "	693 "
Potatoes,	. . . .	10 "	235 "
Oatmeal,	. . . .	3 "	247 "
Total,	. . . .	50 "	= 3444 "

We may reduce any one of these articles and replace it by another article. Suppose it be desired to reduce the meat by two ounces and replace it with sugar. The twelve ounces of beef would give 402 calories. The difference (469 — 402 = 67 calories) must be replaced by sugar giving 116.25 calories per ounce. 67 ÷ 116 = 0.58 ounce of sugar required to replace two ounces of raw beef.

It should be noted that when people are allowed free choice in the selection of their foods, they usually adjust them so as to obtain nearly the following amounts of heat from the three proximate principles :

Of 100 calories obtained from a daily ration :

	PROTEIDS, CALORIES.	FATS, CALORIES.	CARBOHYDRATES, CALORIES.
Nursing infants obtain from	16	43	41
Children, two to six years, from . . .	16.6	31.7	51.6
Well-fed adults, light work, from . . .	19.2	29.8	51
Middle-class, hard work, from	16.7	16.3	66.9
Adults, poorly fed, from	12.1	17	70.9
Aged people, from	17.4	21.8	60.7

—(*Rubner.*)

It is probable, therefore, that these proportions are best suited to the average needs of the body.

Infants fed at the breast use from two to two and a half times as much proteid, about five times as much fat, and about the same amount of carbohydrate, per pound of body-weight, as adults.

Infants fed with breast-milk take less milk than those fed with cows' milk, owing to the more complete digestibility of the former. A child at the breast during the sixth month takes as an average from 770 to 850 c.c. (25.5 to 28 oz.) of milk, and when fed upon cows' milk from 1100 to 1200 c.c. (36 to 40 oz.).

The following is a dietary devised by Austin Flint, and adopted by the New York State Commission in Lunacy, and used in all the State hospitals :

DAILY RATION.

		CALORIES.
Meat, with bone, including salted meats, fresh and salted fish, and poultry, ... 12	oz.	450
Flour, to be used in making bread and in cooking (may in part be substituted by cornmeal and macaroni), ... 12	"	1233
Potatoes, ... 12	"	240
Milk, ... 16	"	325
One egg, ... 2	"	80
Sugar, ... 2	"	230
Butter, ... 2	"	450
Cheese, ... 1	"	130
Rice, hominy, or oatmeal, ... 1½	"	173
Beans or peas (dried), ... 1½	"	150
Coffee (in the berry and roasted), ... ⅝	"	
Tea (black), ... ⅛	"	
Approximately, ... 62	"	3461

In constructing a daily ration we should not only take into account the composition, but the digestibility and the weight of food to be given in twenty-four hours.

The total weight of food for a man of 145 pounds, doing ordinary work, should be between fifty-five and sixty-five ounces.

We have discussed the dynamic value of foods largely as to the amount of heat produced by their combustion. Muscular energy is derived from the conversion of this heat into dynamic energy. It is easy to calculate from the heat generated by a food the mechanical power it will produce. We have but to multiply the number of calories by 3077.6 to get the equivalent in foot-pounds, or by 425.5 to get the equivalent in kilogram-meters.

If we take the European estimate for adults not doing work as 2400 calories, we calculate the equivalent in work as 1,020,000 kilogram-meters, or 3670 foot-tons. For ordinary work the heat required is estimated at 2800 calories, 1,200,000 kilogram-meters, 4280 foot-tons, or 8,562,400 foot-pounds. Taking the American estimate for ordinary work of 3500 calories, we calculate the equivalent as 1,488,-250 kilogram-meters, or 10,771,600 foot-pounds.

It must not be supposed that all the work represented by these figures can be produced by a man by using the above diets.

A considerable part of the energy of the food is used up by the work of the heart and lungs and necessary muscular movements, and a part is lost by radiation of heat from the surface of the body, and a part is lost with the breath, perspiration, urine, and feces.

McKendrick puts the amount of work done by a laborer in eight hours as 125,000 kilogram-meters, or 904.125 foot-pounds. The average daily amount of work performed by laborers is about 1,000,-000 foot-pounds. About one-half as much can be accounted for in

other work, leaving about four-fifths of the energy of the food taken as loss. The best steam-engine can utilize about one-eighth of the total energy of the fuel, while the human body gives about one-fifth of the total energy of its fuel in the form of muscular power. It has been estimated by Professor Gohren that the horse may transform about 32 per cent. of his food into energy, an ox 43 per cent., a man 53 per cent. These results are higher than those of most other observers. The experiments by Rubner on dogs show that they use the fuel with great economy as long as it is not given in excess over the needs of the body. If, however, more food was given than their bodies required, they stored up a part of the excess as fat for a time, but finally reached the point where the excess was all wasted—*i. e.*, there seemed to be a limit to their storing-up of fat, and after that the excess taken was thrown away.

Hunger.—During abstinence from food the body gets its material for the production of heat and the power necessary to carry on the vital processes from the consumption of stored fat and the other tissues. Adults can endure hunger better than children, and full-grown large animals better than young or small-sized animals of the same species. Fat persons can endure hunger longer than lean ones, because the former have more fat to burn. All animals live longer without food, if water be given, than without water. With water, strong men can fast six weeks or more; while young children will often die in from one to two weeks.

Observations on fasting men show that the amount of proteid used up is nearly proportional to the body-weight, when there is an abundance of fat present. In lean persons, however, the proteid used is more in proportion to body-weight. The loss in weight is more during the first hunger-day than in succeeding days, as shown in the following table, giving the observations made upon three fasting men:

NAME OF FASTING MAN.	BODY-WEIGHT IN POUNDS.	GM. OF PRO-TEID USED.	GM. OF FAT USED.	CALORIES PRODUCED.
Cetti, first day, ...	126	95	170	1980
" fifth day, ...	116	67	166	1819
" tenth day, . . .	111	60	165	1786
Breithaupt, first day, .	131	63	162	1771
" second day,	129	62	160	1742
" sixth day, .	124	60	160	1740
Succi, first day, ...	137.5	104	. .	. .
" tenth day, . . .	125	51	170	1795
" twentieth day, .	116	33	170	1709
" twenty-ninth day,	110.4	31	169	1702

It will be seen that, while the proteid used continues to decrease day by day, the fat used remains nearly stationary after the second day. Succi had more fat than the others, and this spared his proteids, as shown in the table.

Cetti and Breithaupt lost a little over a pound a day in weight, while Succi lost a little less than a pound.

The effects of continued fasting, even when an abundance of water is taken, are gradual loss in weight, after a few days a lowering of body-temperature, and when the body-weight has reached two-thirds or one-half the initial weight the nervous system, heart, and other organs lose their function, the pulse becomes feeble, inanition delirium supervenes, then somnolence or coma, and finally death.

COMPOSITION OF COMMON FOODS.—*Gautier.*

	1	2	3	4	5	6	RATIO OF 1:2:3		
NAME OF FOOD.	ALBUMINOIDS AND EXTRACTIVES.	FATS.	CARBO-HYDRATES.	ASH.	WATER.	REFUSE.	1	2	3
Flesh without Bones :									
Beef, fat, ...	183	166	. .	11	640	. .	1	.9	. .
" medium fat, ...	196	98	. .	18	688	. .	1	.5	. .
"	190	120	. .	18	672	. .	1	.63	. .
" salted, ...	218	115	. .	117	550	. .	1	.53	. .
Veal, ...	190	80	. .	13	717	. .	1	.42	. .
Horse-flesh, ...	318	65	. .	125	492	. .	1	.20	. .
Smoked ham, ...	255	365	. .	100	280	. .	1	1.43	. .
Pork, salted and smoked, .	100	660	. .	40	130	. .	1	6.60	. .
Flesh with Bones :									
Beef, fat, ...	156	141	. .	9	544	150	1	.90	. .
" medium fat, ...	167	83	. .	15	585	150	1	.49	. .
" slightly salted, . . .	175	93	. .	85	480	167	1	.53	. .
" corned, ...	190	100	. .	100	430	180	1	.53	. .
Mutton, very fat, ...	135	332	. .	8	437	88	1	2.46	. .
" medium fat, . . .	160	160	. .	10	520	150	1	1.	. .
Pork, fresh, fat, ...	100	460	. .	5	365	70	1	4.60	. .
" salt, fat, ...	120	540	. .	60	200	80	1	4.50	. .
Ham, smoked, ...	200	300	. .	70	340	90	1	1.50	. .
Eggs, white, ...	103	7	7	8	875	. .	1	.07	.07
" yolk, ...	160	307	. .	13	520	. .	1	1.92	. .
Milk, cow, ...	36	40	55	4	865	. .	1	1.11	1.53
" human, ...	19	45	53	1.8	877	. .	1	2.37	2.52
Fish in General :									
Eel, of rivers, entire, . . .	89	220	. .	6	352	333	1	2.47	. .
Salmon, entire, ...	121	67	. .	10	469	333	1	.56	. .

Fish in General line: 135 | 45 | . . | 15 | 740 | . . | 1 | .33 | . .

COMPOSITION OF COMMON FOODS.—*Continued.*

NAME OF FOOD.	1 ALBUMINOIDS AND EX-TRACTIVES.	2 FATS.	3 CARBO-HYDRATES.	4 ASH.	5 WATER.	6 REFUSE.	RATIO OF 1:2:3		
							1	2	3
Fish in General :									
Sole, entire, ...	145	14	. .	11	580	250	1	.09	. .
Perch, "	100	2	. .	8	440	450	1	.02	. .
Cod, fresh, entire, ...	86	1	. .	8	455	450	1	.01	. .
Herring, salted, ...	140	140	. .	100	280	340	1	1.	. .
Salmon, "	200	108	. .	132	460	100	1	.54	. .
Cod, dried, ...	532	4	. .	106	257	100	1	.01	. .
Vegetable Foods :									
Wheat-bread, fresh, ...	88	10	550	17	330	5	1	.11	6.25
Rye-bread, fresh, ...	77	10	480	16	400	17	1	.14	6.25
Wheat, ...	146	12	679	16	140	. .	1	.082	4.68
Rye, ...	90	20	675	19	166	. .	1	.22	7.50
Winter barley, ...	134	28	636	45	130	. .	1	.21	4.74
Oats, ...	119	55	615	30	140	. .	1	.46	5.17
Corn, ...	128	70	599	11	177	. .	1	.54	4.69
Rice, ...	64	4.3	781	6.8	144	. .	1	.06	11.90
Peas, ...	225	20	575	23	145	. .	1	.09	2.55
French beans, ...	225	20	540	24	160	. .	1	.09	2.43
Kidney "	220	15	575	25	130	. .	1	.07	2.61
Lentils, ...	265	25	580	16	115	. .	1	.09	2.19
Potatoes, ...	15	2	200	10	760	. .	1	.09	10.30
Cauliflower, ...	5	. .	20	7	920	. .	1	. .	4.
Apples, ...	5	. .	20	. .	. .	. .	. .	. .	. .
Grapes, ...	7	. .	80	5	820	. .	1	. .	16.
Almonds, ...	242	537	72	29	54	66	1	2.22	.30
Cocoa, ...	140	480	180	50	55	95	1	3.43	1.29
Prepared Foods :									
Bouillon, ...	6	. .	. .	3	985	. .	. .	. .	. .
Butter, ...	7	850	. .	15	119	. .	1	1.21	.1
Lard, ...	3	990	. .	. .	7	. .	1	3.30	. .
Swiss cheese, ...	335	250	. .	38½	346	. .	1	.75	. .
Parmesan cheese, ...	441	159	. .	57	275	. .	1	.36	. .
Extract of beef (Liebig's), .	304	. .	. .	175	217	. .	. .	. .	. .
Wine (red Bordeaux), . . .	. .	. .	83	. .	830	. .	. .	. .	. .
Porter, ...	7	. .	67	4	871	. .	1	. .	9.57
Beer, ordinary, ...	5	. .	70	3	. .	. .	1	. .	.15
" light, ...	7	. .	48	2	916	. .	1	. .	6.85

The Digestibility of Foods.—A knowledge of the digestibility of foods is of great importance. We live, not upon the food we eat.

but upon what we digest and absorb. The following table gives the percentage of the various foods usually digested by man:

NAME OF FOOD.	WEIGHT OF FOOD EATEN, IN GRAMS.		AMOUNT ABSORBED, IN PER CENT.				
	Moist Condition.	Dry Substance.	Dry Substance.	Proteids.	Fats.	Carbohydrates.	Ash.
Meats (roasted), . .	884	367	95	97	95	. .	82
Egg, ...	948	247	95	97	95	. .	82
Milk, ...	2470	315	92	89–99	95–97	100	63
Milk and cheese, .	2490	420	94	96	97	100	74
White bread, . . .	860	617	95	79	. .	99	93
Brown bread, . . .	1360	765	85	68–78	. .	89	64
Macaroni, ...	695	626	96	83	94	99	76
Corn-bread, . . .	750	641	93	85	83	97	70
Corn-bread and cheese, ...	. .	780	96	93	91	96	81
Rice, ...	638	552	96	80	93	99	85
Peas (in soup), . .	600	521	91	83	. .	96	68
Potatoes, ...	3078	819	91	68	96	92	84
Butter, ...	. .	. .	. .	. .	98	. .	. .
Oleomargarine, . .	. .	. .	. .	. .	96	. .	. .
Beets, ...	. .	. .	. .	72	. .	82	. .
Mixed Diets:							
1 liter milk, chopped meat, white bread, butter, and an egg, . . .	. .	360	89	91	95	100	. .
1 liter milk, 300 gm. of meat, 175 gm. bread, 60 gm. butter, . . .	1540	. .	. .	94	95	99	. .
Meat, peas, cakes, rice, cheese, butter, and beer, . .	4500	805	91	83	85	96	72
Meat, oatmeal, potatoes, bread, cheese, peas, and butter, ...	4330	787	87	78	77	91	59
Coarse bread, potatoes, herring, bacon, milk, salt meats, ...	3910	898	87	78	82	93	70

It will be noticed in this table that the proteids of milk and cereals are less completely digested than those of meats. Children, however, do better than adults in digesting the proteids of milk. In considering this question, we must not neglect the idiosyncrasies of certain people. What is digested by one is often difficult to digest by another. Diseases of the digestive canal frequently interfere with the digestion of food. Such variations from the normal can not be taken into account in considering the digestibility of foods. In the table on pages 573 and 574 will be found the proximate composition of the ordinary articles of diet

Circumstances that Affect the Digestibility of Foods—Source.—The proteids of animal origin are more easily and completely digested than those from the vegetable kingdom. The same may be said of fats. We know, in regard to the carbohydrates, that the starch from one plant is often more digestible than that from another. We know of no explanation for this. With regard to meat, some kinds of flesh are more easily digested than others by artificial gastric juice; thus, fish is more difficult to digest than meat; white flesh is more easily digested than dark, raw beef than smoked.

Observations made in cases of gastric fistula, upon the time food stayed in the stomach, have shown that meat remains from two and one-half to five hours, the most digestible being lamb, beef, mutton, fish, veal, and pork, in the order named. Some starchy foods—as rice, barley, tapioca—remain two hours or less in the stomach, while others, such as beans, peas, and potatoes, remain two and one-half hours; white bread three hours, and brown bread four hours.

Bulk or Volume of Food.—A bulky food throws excessive work on the stomach, causes discomfort, and all parts of the food can not so well come in contact with the walls of the stomach. The same amount of nutriment in smaller space is more easily digested. One objection to a vegetarian diet is in the fact that proteids are so diluted by insoluble cellulose and unnecessary starch that large volumes of food must be taken to obtain the requisite 15 to 18 gm. of N daily. The carbohydrates, too, are apt to undergo fermentative changes, and the gases so formed give rise to flatulence and discomfort.

The Reaction of Food.—As a rule, food should be slightly alkaline to excite a flow of gastric juice; too much alkali, however, neutralizes the gastric acidity and thus hinders digestion. Too much acid, such as lemon-juice, vinegar, etc., may diminish digestion, and ultimately lead to serious disorders of the walls of the stomach.

Cooking of Food.—The cooking of food is not always a necessity, although it serves several useful purposes. It destroys parasites and the danger of infection. It breaks up the starch grains in vegetable foods and makes them more easily affected by the digestive juices. It converts the insoluble collagen of animal foods into soluble gelatin, and disintegrates the connective tissue.

Of the two methods of cooking, roasting and boiling, the former is the most economical, as by its means the exterior is coated over with a coagulated coat, which preserves the flavor and juices of the interior. Boiling renders the proteids more insoluble than they are in the raw state, but this is counterbalanced by the greater solubility of the connective tissue.

Artificial Digestion.—It is frequently found necessary, with persons of feeble digestion, to partially digest the food before it is administered. Artificial gastric juice, pancreatic juice, and juices of the papaw plant and the pineapple are employed for this purpose. The food to be digested is warmed to the temperature of about 40° C. (104° F.). The digestive agent is then added, and it is allowed to react for a time limited by circumstances. In such cases we usually present to the enfeebled stomach half-digested foods. In the case of meats, the peptonization is seldom carried beyond the formation of albumose. It is the aim, usually, to prepare peptone, if at all, in very small quantities. The best commercial preparations sold under the name of peptones are chiefly albumoses containing but a small quantity of peptone. Indeed, the value of peptone as a food seems to be less than that of albumose.

Animals fed upon peptone instead of albumin or other undigested proteid lose weight. The following table shows the relative value of the different proteids upon the metabolism of nitrogen :

KIND OF PROTEID.	NITROGEN INTAKE.	NITROGEN OUTGO.	BALANCE.
Albumin, ...	{ 8.917 gm. { 8.917 "	5.802 gm. 6.370 "	+ 3.115 gm. + 2.544 "
Albumose, ... 8.909 "		6.422 "	+ 2.487 "
Peptone, ...	{ 8.953 " { 8.953 "	10.476 " 10.312 "	— 1.523 " — 1.359 "

That is, when the same amounts of the three proteids are fed, the first two nourish the body equally well, while peptone fails to assimilate in sufficient amount to keep up the nitrogen balance.

Artificially digested foods are usually bitter, if the digestion is carried too far. What this bitter substance is, is unknown. It is not albumose or peptone.

Absorption of Foods.—The absorption of the digested foods is more a physical and physiological process than a chemical one. It is a process of osmosis, modified by special conditions. On one side of the mucous membrane of the intestines we have the blood and lymph, and, on the other, a concentrated solution of easily diffusible salts, peptones, dextrin, levulose, soaps, and fat in a state of fine emulsion. The soluble carbohydrates—that is, dextrin, dextrose, levulose, etc.—absorb slowly, pass principally into the rootlets of the portal vein, and are carried to the liver, where a part is stored up as glycogen, the remainder disappearing.

The ultimate product of the hydrolysis of proteids, under the influence of pepsin and trypsin, and known as peptone, is the most diffusible proteid known. It is absorbed partly by the lymphatics, also

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somewhat by the blood-vessels, but is not found as peptone in the blood. If injected into the blood it disappears inside of twenty minutes. If very large doses are injected, the animal suffers profound disturbances, and usually death. Most of the peptone is reconverted into albumin while passing through the membrane. Very little unchanged proteid is absorbed. Egg-albumin, as well as myosin and alkali-albumin, when mixed with a small quantity of sodium chloride, are absorbed in small amounts. The large intestine absorbs them more readily, the limit being six grams of albumin or fifty grams of egg-white per day. The soluble soaps are easily absorbed. Very little of the fat undergoes saponification before absorption, but it is emulsified after a small amount of saponification. This emulsion is quite readily absorbed by the lacteals, and soaps can be detected in the portal blood, but rapidly disappear. No free fatty acids have been found in the blood. Alcohol, in part at least; tartaric, malic, citric, and lactic acids; glycerin, inulin, and vegetable mucin are absorbed from the intestine; chlorophyll is not absorbed; hematin only partly; indigo, madder, alkanet, turmeric, and many other vegetable coloring matters are absorbed. The gums and pectin, not being peptonized, are not absorbed. Poisons are sometimes rapidly absorbed, and at other times slowly. Some organic poisons are stopped by the liver, while others are not.

Assimilation.—The function of food is to give heat and cell-energy—mental, nervous, and muscular. The ultimate form in which food leaves the body is H_2O, CO_2, NH_3, uric acid, and urea. The intermediate forms and products, besides those of animal heat and motion, are as yet little known. Just what proportion of the food actually enters into the formation of the tissues before undergoing oxidation, and how much of it is oxidized merely to furnish heat, has been the subject of dispute, but the weight of evidence now seems to be that no proteid food is directly oxidized.

Liebig divided food into flesh-formers and heat-producers. The nitrogenous elements he termed the plastics, or flesh-formers. We now know that they produce heat and fat, as well as do the carbohydrates. Formerly it was supposed that the blood was the seat of oxidation in the body, but now this view is abandoned. It is in the solid tissues where the principal oxidation takes place, but not within the cells. While it is probable that most of the food becomes assimilated and takes the place of the tissues which are disintegrated, it is certain that not all of the food taken enters into the composition of the tissues, or is assimilated. It is quite probable that a part of the glucose, at least, undergoes direct combustion in the capillaries of muscular tissue during its contraction.

We have seen that the proteids are all absorbed as peptones, are converted into serin or serum-albumin and serum-globulin, during or immediately after absorption, and circulate in the blood and lymph in this form.

By slight modifications, which do not greatly modify their chemical composition, but rather their physical properties, they are converted into myosin, casein, ossein, gelatin, etc., to suit the needs of the different structures. These changes are due in many cases to loose combinations with various inorganic salts.

The carbohydrates, we have seen, are absorbed in the form of dextrose. It is also stated by some authorities that a small quantity of dextrin and cane-sugar may be absorbed from the stomach, when they enter the venous circulation. It is more likely that dextrose, when taken with food, is absorbed here, as it is more diffusible than either of the others.

The dextrose which is absorbed from the intestines is changed by the liver into glycogen, although this substance is also prepared from the proteids of the protoplasmic tissues. Glycogen is also found in many organs of the body, as in the fetal placenta, the skin, lungs, kidneys, muscles, and epithelium. It is especially abundant in the muscles (0.4 to 0.8 per cent.). It is augmented by a diet rich in starch, sugar, or dextrin. Dextrose is found in the muscle-juice as well as in the blood.

The glycogen of the muscles accumulates during repose, but disappears during prolonged work, and may be one of the decomposition products of proteids.

The fats are absorbed principally as such, and are distributed throughout the body. The animal body also derives fat from the conversion of sugar or glycogen, and from the destruction of proteids of cell-protoplasm.

The chemical processes involved in the appropriation of the various food-substances we have been considering are not thoroughly known ; but by some sort of combination the dead circulating proteid becomes a part of the living cell.

The most important tissue of the body, because most abundant, is the muscular. Half the proteid material of the body and half the water exist in the muscles.

We can get some idea of the use of foods in the animal body by feeding experiments upon animals, and striking a balance-sheet between the matter taken into the body in a given time, including food, drink, and air, and the total excretions, including urine, feces, perspiration, and breath.

The following table will illustrate what is meant by such a balance-

sheet. The data for such a balance-sheet can only be obtained by use of a respiration calorimeter :

EXCHANGE OF MATERIAL ON ADEQUATE DIET. — *Ranke.*

INCOME.			EXPENDITURE.		
FOOD.	NITROGEN.	CARBON.	EXCRETION.	NITROGEN.	CARBON.
Proteid, 100 gm., ...	15.5	53	Urea, 31.5 gm., . . . } Uric acid, 0.5 gm., . }	14.4	6.16
Fat, 100 gm., ...	. .	79	Feces, ...	1.1	10.84
Carbohydrate, 250 gm., .	. .	93	Respiration (CO_2), . . .	. .	208.00
Total, ...	15.5	225	Total, ...	15.5	225.00

Relation between Proximate Principles of Food.—It has been found that the relation between carbon and nitrogen in our food should be 250 to 15, or 16.6 to 1. The proportion of these elements in proteids is 53 to 15, or 3.5 to 1. If a man should attempt to live upon lean meat, he must consume 2 to 3 kilograms (5 to 6 pounds) of beef to get the requisite amount of carbon. This quantity would contain more nitrogen than the body needs, and more than can be easily digested or oxidized if absorbed, and more than the kidneys can excrete. This overworking of the kidneys would tend to produce chronic inflammation, and the accumulation of nitrogen would tend to produce gout and other troubles.

If the quantity of meat be adjusted for the proper amount of nitrogen, there would not be enough carbon to supply heat, and the body would lose weight. A pure meat diet, therefore, can not be maintained for a long time without serious injury.

The same thing is true, to a limited extent, with carbohydrates in the form of cereals, and especially in the flour made from them. By reference to the table on page 568 it will be seen that to get the requisite nitrogen in wheat-bread, 1.3 kilograms (2.8 pounds) of it must be eaten, while less than half that amount would furnish the carbon.

In the practical construction of a diet, we first take enough meat to supply sufficient proteid, and then supplement this with sufficient car-

bohydrate and fat to furnish the necessary heat. The non-nitrogenous foods — *i. e.*, fats and carbohydrates — are thus termed **proteid-sparing foods.** The same term may be applied to gelatin, as this is its chief value as a food. The fats and carbohydrates, especially the latter, oxidize more readily than the proteids, and in this way protect the proteids, as well as the fats, from loss. The fats and carbohydrates seem to be able, to a certain extent, to replace each other without detriment. Fats and carbohydrates are both manufactured in the body from proteids, but this change is prevented by an abundance of the former. In diabetes mellitus this conversion of proteids into dextrose is very great, and with consequent rapid loss of flesh and strength. Supplying carbohydrates does not then spare the proteids. Fats are formed in the body from the proteids of the tissues, as one of the retrograde or destructive changes. Hence it forms as a step in **degenerations of tissue.** Fats are also stored from the fat taken as food, or they are formed from carbohydrates.

Food Accessories.—By food accessories are meant those substances taken with food, such as alcohol, condiments, stimulants, etc.

Alcohol, when taken in moderate amounts, is burned in the body, and gives potential energy. One gram of alcohol in burning produces 7.054 calories, while dextrin, which occurs with alcohol in malt liquors, gives 4.117, and glucose 3.739. These substances are all capable of being used as combustibles.

While alcohol acts as a producer of force, it, at the same time, can not be regarded as equal to the carbohydrates. Like them, it spares the nitrogenous waste, shown by its power of diminishing the excretion of urea. In large quantities, however, it increases the excretion of urea, with the destruction of nitrogenous tissue. In this respect it behaves like certain active poisons, as arsenic and phosphorus. Like these poisons, it leaves a residue of fat after the decomposition of the tissues, and may lead to the accumulation of fat in certain organs.

There is another difference between the action of the carbohydrates and alcohol, and that is in the local irritant action of the latter on the stomach and other internal organs, and the central nervous system. While it serves to produce heat, spare the proteids, and stimulate the heart, it, at the same time, has a certain injurious action upon some of the tissues. Its paralyzing action upon the nervous system is shown by the dilatation of the capillaries, giving a sense of warmth in cold weather. This dilatation of the capillaries favors the loss of heat by radiation and the lowering of the general temperature. The larger the dose, the greater its paralyzing effect upon the nerves controlling the capillary circulation, and the greater the elimination of heat. The effect of a small amount of alcohol, well diluted, upon

digestion, is to assist it. The continued use of the stronger solutions (whisky, brandy, gin, etc.) produces a catarrhal inflammation, and, when used in excess, acute gastritis. The appetite very often either fails entirely or is singularly modified to crave only meats as a diet. This leads to the overproduction of urea and uric acid, with gout, rheumatism, cystitis, or nephritis. Statistics based upon observations made upon thousands of men put under the same conditions, as in armies, have shown that "soldiers, in war or peace, in all climates, in excessive heat or cold, in rain and the hardships of the severest marches, endure best when all alcoholic drinks are withheld." (A. Baer.)

We must, therefore, regard alcohol as an expensive food, with certain good results when taken in reasonably small amount and well diluted, as in claret and beer ; but when taken in larger quantity it acts as a poison, which interferes with the normal metabolism, increases nitrogen waste, and perverts the function of digestion, the nervous system, and some glandular organs. The net result of its action in the body, when taken in considerable quantities, is injurious. It has been estimated that the human body can burn about two fluidounces of absolute alcohol per day. This will represent about 4 to 5 ozs. of whisky or brandy, 10 ozs. of sherry or port wine, 20 ozs. of claret, champagne, porter, or Bass's ale, or 40 to 60 ozs. of American beers.

Tea, coffee, maté, and cocoa are used principally as nerve-stimulants. The first three owe their stimulant properties to caffeine (trimethyl-xanthin) ; cocoa to the related alkaloid, theobromine (dimethyl-xanthin). It is noteworthy that all people in all climates make use of some plant that contains these or similar alkaloids. The most of the caffeine so taken is destroyed, but when the amount taken reaches 0.5 gm. (8 grs.) a portion of it passes into the urine.

A cup of coffee, according to Bunge, contains about 0.1 gm. caffeine, and about the same amount is contained in from 2 to 10 gm. of dry tea-leaves. Coffee has little influence upon the excretion of urea, and does not, therefore, act injuriously unless taken in doses sufficient to overstimulate the nervous system. It does, however, sometimes act injuriously upon stomach digestion. The same may be said of tea and cocoa. Chocolate is not only a stimulant, but a rich food. It contains about half its weight of fat, and, besides, about 12 per cent. of nitrogenous matter. It is, therefore, a concentrated food.

Beef-tea and **beef-extracts** owe their value to the extractives, which are stimulants and proteid-savers. Some have regarded the inorganic salts as having a large share in their refreshing effects. They have little food value. The gelatin contained in soups and beef-tea saves the waste of nitrogenous tissue during fever, and thus retards the

loss of strength, but does not add to the construction of tissue or blood. Munk states that 100 parts by weight of gelatin is equal to 36 parts by weight of albumin, or 173 parts of muscle. It can, therefore, partly spare the body the necessity of using up its tissues during illness, but can not entirely take the place of proteids. It is, therefore, a valuable proteid-saver. It is also a fat-sparer, but not as valuable for this purpose as the carbohydrates. A part of the value of meat-soups and beef-teas, made in the usual way, is in the gelatin they contain. Liebig's extract and similar preparations owe their effects principally to the extractives, creatin, xanthin, hypoxanthin, carnin, lactic acid, gelatin, and inorganic salts. They contain about 78 per cent. of solid matter, of which about 60 per cent. consists of organic matters, principally composed of these extractives, and 18 per cent. of salts.

Condiments, such as pepper and other spices, are useful only as means of whetting the appetite. They probably act by mildly irritating the mucous membranes, causing an increased flow of the digestive juices.

The Source of Muscular Energy.—We have heretofore spoken of the oxidation or burning of the food in the body as the source of all heat, muscular power, and nervous energy. We have also seen that the food does not burn as such, but it supplies the place of tissue that has burned, and thus maintains the equilibrium. When the body neither loses nor gains weight, there is just as much food-material converted into tissue as there is tissue destroyed.

The action of the food may be roughly illustrated by a tube open at both ends and filled with marbles. If we push a marble in at one end, one is pushed out at the other. If two or three are put in, two or three are pushed out. The marbles that are pushed out are equal in number, kind, and weight to those pushed in, but are not the same marbles. So the food enters the tissues on one side and crowds out waste products on the other. When more food is taken, more waste is crowded out and excreted.

The changes that are observed when a muscle contracts are, at first, an elevation of temperature, an increase in the circulation in the muscle, brought about by a dilatation of the capillaries, and an acid reaction from sarcolactic acid. The elevation of temperature is nearly proportional to the energy of the contraction, or the work done by the muscle.

It has been demonstrated that the muscle-glycogen diminishes rapidly during the contractions, and gradually accumulates when the muscle is in repose ; also that the glucose disappears from the blood flowing through a muscle when at work. Chauveau showed, by analysis of the blood entering and leaving the masseter muscle of a horse :

First. That the amount of blood traversing a muscle is 2.5 to 3 times more during work than during repose.

Second. The oxygen consumed by 1000 gm. of muscle and the CO_2 formed are $3\frac{1}{2}$ times as much during work as during repose.

Third. That the glucose which disappears from the blood in passing through the muscle in a half-hour is $3\frac{1}{2}$ times as much during work as during the same time in repose.

At the same time the glycogen largely disappears from the muscle.

The greater part of the real energy of a muscle comes from the oxidation of glucose, or glycogen.

A part of these bodies is changed into lactic acid, and a small amount of nitrogenous waste takes place, with the formation of fat, creatin, and other leucomaines which accumulate in the muscle.

Urea and uric acid are not much increased by muscular work, but the myosin and globulin seem to slightly diminish, and are probably converted into creatin, fat, etc. The principal force for the production of work comes from the oxidation of fats and carbohydrates. This explains why the urea excreted is not in proportion to the work performed by a man. The accumulation of leucomaines and the exhaustion of glycogen are the causes of fatigue.

It has been shown that a laborer who works ten hours a day must have, to keep his body in a good state of health, over and above that necessary for a state of idleness, the following amounts of nourishment (Gautier) :

42 gm.	of albuminoids, giving	163	calories of heat.
12 "	" fat, "	102	" "
160 "	" carbohydrates, "	693	" "
	Total,	958	" "

From this table it appears that 81 per cent. of the work done by the laborer comes from the burning of the fats and carbohydrates, and 19 per cent. from the proteids, which latter must be replaced, molecule for molecule, by food.

The 42 gm. of proteids consumed ought to produce 14 gm. of urea, if entirely consumed and excreted in this form. In fact, only about one-sixth of this amount is obtained. There is, then, but a very small increase in urea excreted during work over that excreted in idleness. Fick has demonstrated that about 33 or 34 per cent. of the total intramuscular combustion appears in the form of muscular work, while the remainder is thrown off as heat. This, indeed, is the principal source of animal heat. Helmholtz estimates that, of the total heat produced by oxidation in the body, about 7 per cent. is represented by mechanical work and 74 per cent. is radiated from the skin, and the remaining 19 per cent. is eliminated by the lungs, urine, and feces.

DIGESTION.

Digestion has for its object the preparation of food for the nourishment of the tissues. There is an external and an interstitial digestion. External digestion is the preparation of the food for absorption; interstitial digestion is the more hidden process by which the food in the interior of plants and animals is modified and made available for nutrition. External digestion is illustrated by the manner in which certain lower animals take their food, as, for example, the amœba, which rolls itself about its food, extracts the nutriment, and unrolls to allow the debris to escape. In the Venus fly-trap we have an example of the same process in plants. The alimentary canal is a prolongation of the skin, and may therefore be considered as being outside of the body.

Reserves of food are such portions as are stored up in the bodies of plants and animals for future use, such as fat and glycogen in animals, and starch and sugar in plants.

Digestion is carried on by means of soluble ferments or enzymes. The number of ferments employed in the digestion of the food used by man is not accurately known. There are at least seven or eight of them. The following table presents these ferments, with their origins and the changes which they produce:

TABLE OF THE DIGESTIVE JUICES AND THEIR FERMENTS.

DIGESTIVE JUICE.	FERMENTS CONTAINED IN THEM.	ACTION ON FOOD-MATERIALS.
Saliva.	Salivary diastase or ptyalin.	Changes starch into dextrin and maltose.
Gastric juice.	a. Pepsin.	Changes proteids into peptones in an acid medium.
	b. Curdling ferment.	Curdles the caseinogen of milk.
Pancreatic juice.	a. Trypsin.	Changes proteids into peptones in alkaline and neutral media.
	b. Curdling ferment.	Curdles the caseinogen of milk.
	c. Pancreatic diastase.	Changes starch into acroodextrin, maltose, and dextrose.
	d. Emulsive ferment.	Emulsifies and partially saponifies fats.
Bile.	(?)	Assists in emulsifying fats.
Intestinal juice.	a. Invertin.	Changes cane-sugar into invert-sugar, maltose into dextrose, and lactose into dextrose and galactose.
	b. Curdling ferment (?).	Curdles the caseinogen of milk.

The Saliva.—The first fluid to which aliments are subjected is the saliva. The saliva is the combined secretion of the parotid, submaxillary, and sublingual glands, mixed with mucus from the mucous membrane of the mouth. It is a slightly turbid, viscid, frothy fluid, without taste or odor, slightly alkaline in reaction, and of a sp. gr. from 1002 to 1008. It contains about 0.5 per cent. of solids, of which 0.2 per cent. is salts, and the rest ptyalin, globulin, serum-albumin, mucin, and salivary corpuscles.

MIXED SALIVA—HUMAN.

	(JACUBOWITSCH.) PER CENT.	(HAMMERBACHER.) PER CENT.
Water, ...	99.51	99.42
Solids, ...	0.48	0.58
Soluble organic bodies (pytalin, etc.), . .	0.13	0.14
Epithelium, ...	0.16	0.22
Inorganic salts, ...	0.182	0.22
Potassium sulphocyanate, ...	0.006	0.004
Potassium and sodium chlorides, ...	0.084	. . .

The alkaline reaction is due to the presence of alkaline carbonates and phosphates. The alkalinity differs in different individuals, and in the same individual at different times in the day, and may become neutral or acid without disturbance of health, especially between meals. Pathologically, it may become more alkaline, or even decidedly acid. The salts present are $HNaCO_3$, Na_2CO_3, KCl, NaCl, KCyS, Na_3PO_4, the sulphates and phosphates of calcium and magnesium, ammonium nitrate, and sometimes urea. It contains free O, N, and CO_2 in solution. It is richer in CO_2 than blood. On exposure to the air the CO_2 escapes, when $CaCO_3$ and $Ca_3(PO_4)_2$ are precipitated on the teeth, giving rise to the deposit known as "tartar."

The parotid secretion is clear and watery, rich in ptyalin and poor in mucin. The sublingual is richest in ptyalin, is strongly alkaline, is viscid, and traces of cholesterin and fat have been found in it. The submaxillary is more alkaline than the parotid, is rich in corpuscles and mucus, but poor in ptyalin. The saliva is increased by the stimulation of certain nerves, or by the irritation of pepper, alkalies, and food, or even the thought of food. The saliva of irritation is alkaline, and contains little or no ptyalin. The secretion is increased in quantity by pilocarpine and eserine, but diminished by atropine.

In the saliva of the new-born, only that secreted by the parotid contains ptyalin, while it appears in the submaxillary after about two months.

Uses.—The saliva moistens and lubricates the food and converts starch and glycogen into soluble starch, dextrin, and maltose. One of its most important uses is to liquefy the contents of the stomach by its solvent power upon the starchy elements. The saliva acts best in a neutral or faintly acid solution, if the acidity be due to organic acids. It does not act in the presence of free HCl, or HCl and pepsin. Its activity is increased by small quantities of NaCl, Na_2SO_4 (0.4 per cent.), NH_4Cl, CO_2, acetate of quinine, strychnine, and morphine. Tea has an intense inhibitory effect, coffee and cocoa very little effect. The saliva becomes more alkaline in very acid conditions of the gastric juice, and even more abundant, giving the disease known as pyrosis, or water-brash. The saliva acts very feebly on uncooked starch. A peptone-forming ferment has been found in the saliva.

GASTRIC JUICE.

The gastric juice is a thin, transparent, faintly yellow, acid fluid, of sp. gr. 1001 to 1010. It contains from 0.5 to 1 per cent. of solids, of which two-thirds or less is organic matter. The pyloric end of the stomach secretes the alkaline fluid, or **succus pyloricus**, which is said to convert starch into sugar, and to digest albumin when acidified with HCl, and to dissolve gelatin. The thick, slimy secretion of the stomach, in a state of rest, is neutral or even alkaline. The normal secretion of the stomach is a mixture of these fluids. Its composition is as follows:

ANALYSIS OF GASTRIC JUICE (HUMAN) MIXED WITH SOME SALIVA.

(*C. Schmidt.*)

	PER CENT.
Water,	99.44
Solids,	0.56
Organic substances (pepsin and peptones),	0.32
Free hydrochloric acid,	0.25
Sodium chloride,	0.14
Potassium chloride,	0.05
Calcium chloride,	0.006
Phosphates of lime, magnesia, and iron,	0.015

The acidity of the gastric juice of some of the lower animals, especially the dog. is greater than that of man. In the dog it is nearly six times that of man ; in the fish it may even be seven times as much as that of man. The organic matter present is chiefly pepsin and a little mucin, and amounts to about 0.3 per cent. The acidity of the gastric juice is chiefly due to free hydrochloric acid, acid salts, and organic acids. The organic acids are chiefly lactic and butyric, with occasionally acetic. These are not secreted in the gastric juice itself, but are produced partly by the decomposition of their salts in the foods taken, and partly by fermentative action ; so that in the earlier stages of digestion the acidity is chiefly due to organic acids, but, in the later stages of digestion, chiefly to hydrochloric acid, which is present in quantities varying from 0.1 to 0.4 per cent.

The HCl is probably produced by one of the following reactions:

$$(\text{1})\ 2Na_2HPO_4 + 3CaCl_2 = Ca_3(PO_4)_2 + 2HCl + 4NaCl.$$
$$(\text{2})\ CO_2 + 2NaCl + H_2O = Na_2CO_3 + 2HCl.$$
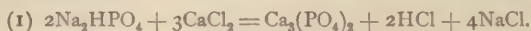
Others think that the HCl in the gastric juice is in combination with some of the amid bodies, as leucin or tyrosin, which are found in all glands. Liebermann claims that there exists an acid-reacting compound of lecithin and albumin, always found in the mucous membrane of the stomach, which takes up the Na_2CO_3 of the second or the $NaHCO_3$ of the third reaction given above. The compound thus formed gradually sets free the Na_2CO_3, which passes into the blood. Besides HCl and the organic acids above spoken of, the gastric juice contains ferments, two of which are of special interest—namely, pepsin and rennin, which have been described elsewhere. There exist also in the stomach, at times, certain gases, especially CO_2. O, N. H, and CH_4. It is evident that these gases are the result of the microbial fermentation of aliments.

Action of the Gastric Juice.—The gastric juice acts especially upon the proteids. It modifies them by transforming them successively into syntonin, or acid albumin, then into propeptones or albumoses, and finally into peptones. These compounds have already been described. It is evident, from what has just been said, that during digestion a part of the HCl only is in the free state, while a part of it is in combination with the proteids, in the state of acid-albumin.

The phenomena of gastric digestion are due to the hydrolysis of the albumin and a breaking-up of these molecules into simpler ones. The peptones are richer in H and O than the proteid bodies from which they were produced.

THE CLINICAL EXAMINATION OF THE GASTRIC CONTENTS.

Before beginning the study of the methods for the clinical examination of gastric juice, it will be well to consider a few of the principles of volumetric analysis.

Because of the rapidity and ease with which quantitative analyses can be made by means of volumetric solutions, this method is almost universally adopted in clinical work. As most of the quantitative processes described in the following pages of this book depend upon the use of volumetric solutions, it is necessary for the student to understand their preparation, the principles of their use, and the apparatus employed.

Volumetric Quantitative Analysis, or Estimation.—By **volumetric analysis** is meant the quantitative estimation of a substance, by adding to it a measured volume of liquid containing a known amount of the reagent, and depending upon an indicator to show when the precipitation or reaction is completed. This process is called **titration.**

Volumetric analysis requires :

1. A graduated vessel, from which accurately measured portions of the reagent liquid may be delivered, called a **burette.**

2. A solution of the reagent, of known chemical power, and called a **standard** or **volumetric solution.**

3. The decomposition produced by chemical in the standard solution with the substance to be estimated must be either such that by itself or by the aid of an indicator *its completion is unmistakably evident to the eye,* and thus the quantity of the substance with which it has reacted may be calculated.

Measuring Instruments.—The apparatus needed for the volumetric methods are usually few and inexpensive. An expensive balance is not essential for the methods to be mentioned below, as the standard solutions are to be had of wholesale druggists or chemical dealers, or can be prepared by any competent pharmacist. A **burette** is a graduated tube holding from 25 c.c. to 100 c.c., and provided with a stop-cock at one end and terminating in a tube of small caliber. The most convenient burette is one of 50 c.c. capacity, and graduated to 0.1 c.c. (See Fig. 64.)

Pipettes (Fig. 66) are graduated tubes, drawn down at one end to a small opening, and intended to be filled by suction at the upper end, after which the finger is pressed upon the upper end to control the flow. A graduated flask is a glass flask having a narrow neck,

upon which is a mark denoting its capacity when filled to this mark. The most convenient sizes for general purposes are 50 c.c., 100 c.c., 250 c.c., and 1000 c.c. It is convenient to have a 10-c.c. and a 25-c.c. graduated cylinder.

Standard Solutions.—A standard solution is a solution of a chemical substance, containing a known amount of the substance in a measured volume of liquid. It is usual to express the strength of such solutions in the number of grams of the active ingredient to the liter, or 1000 c.c., of the solution.

A **normal standard solution** is one made to contain the chemical equivalent of one atom of hydrogen, or any other monad element, expressed in grams, dissolved in one liter.
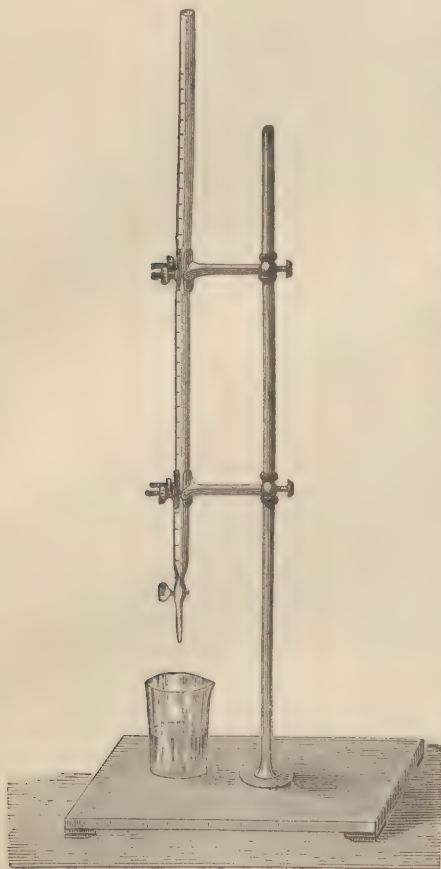
FIG. 64.—GRADUATED BURETTE. FIG. 65. FIG. 66.

Thus: HCl is the chemical equivalent of Na, Ag, Br, I, or H.
$$HCl + AgNO_3 = AgCl + HNO_3.$$
$$HCl + NaOH = NaCl + H_2O.$$
$$HCl + NaI = NaCl + HI.$$

The molecular weight of HCl is $35.5 + 1 = 36.5$. The normal solution of HCl will then be made to contain 36.5 gm. by weight of HCl to the liter. The chemical equivalent of H_2SO_4 in Na or H is twice that of HCl, or one molecule of H_2SO_4 will neutralize Na_2. Hence the normal solution will contain one-half its molecule, expressed in grams, dissolved in one liter, or $98 \div 2 = 49$ gm. A normal solution of oxalic acid, $H_2C_2O_4.2H_2O$, will also contain one-half its molecular weight, dissolved in a liter. A normal solution of sodium hydroxide will contain the molecular weight expressed in grams, because NaOH is the equivalent of HCl, Br, I, or any other monad.

A decinormal solution is one containing one-tenth the active ingredient of the normal solution, or one-tenth the chemical equivalent of hydrogen, expressed in grams, dissolved in a liter. It is often made from the normal solution by diluting 100 c.c. of the latter to a liter with distilled water. A $\frac{1}{50}$ normal and a $\frac{1}{100}$ normal solution or a centinormal solution are sometimes used. A normal solution is frequently expressed thus : $\frac{N}{1}$; a decinormal, $\frac{N}{10}$, or $\frac{1}{10}N$; and a centinormal, $\frac{1}{100}N$, or $\frac{N}{100}$.

Preparation of Decinormal Sodium Hydroxide.—As commercial sodium hydroxide is not of definite composition, it is usually prepared by titration against a normal or decinormal solution of oxalic acid. To prepare a normal solution, weigh out exactly 63 gm. of pure crystallized oxalic acid, $H_2C_2O_4.2H_2O$, taking care that it is free from any evidence of extra moisture or efflorescence of the crystals, and dissolve this in one liter of distilled water. Weigh out about 50 gm. of best commercial NaOH, and dissolve this in water, cool, pour into the 1-liter flask and make up to one liter.

To "*standardize*" this solution proceed as follows : Measure out into a beaker 10 c.c. of the solution, add three drops of a 1 per cent. alcoholic solution of phenolphthalein, and run in the oxalic acid from a burette until the pink color is just discharged. Suppose 12 c.c. of the acid solution be required to do this. Then 10 c.c. of the NaOH solution contain the amount of NaOH that should be contained in 12 c.c. ; 100 c.c. will contain the amount that 120 c.c. should contain. To make a normal solution of this solution, 20 c.c. of water must be added to every 100 c.c. We may calculate the amount of water to be added to any number of cubic centimeters by the following proportion :

$$10 : 12 : : \text{any measured volume} : \varphi.$$

Or, we may calculate the number of cubic centimeters to be used to make 1000 c.c. by the proportion :

$$10 : 12 : : \varphi : 1000.$$
$$10 \times 1000 = 10,000.   10,000 \div 12 = 833.3 \text{ c.c.}$$

From this normal NaOH solution we may make a decinormal solution by measuring out 100 c.c., putting this into a liter flask and filling to the mark on the neck with distilled water.

Statement of results of a titration are expressed by two methods: Either by calculating the total amount or the percentage of acids present, or by calculating the number of cubic centimeters of decinormal alkali required to neutralize the acid of 100 c.c. of the fluid. In the case of total acidity, or total organic acids, or in the estimation of acid salts of gastric juice, it is impossible to state the percentage of these causes of acidity, except in equivalents of some acid, as HCl, which is usually selected. Suppose, for example, that the amount of $\frac{N}{10}$NaOH required to give a decided pink color in 10 c.c. of the filtered fluid containing phenolphthalein be 6 c.c.: It would require $6 \times 10 = 60$ c.c. for 100 c.c. of fluid. Each cubic centimeter of the NaOH solution neutralizes 0.00365 gm. of HCl. Sixty c.c. would neutralize an acidity the equivalent of $60 \times 0.00365 = 0.2190$ gm. of HCl in 100 c.c., or 0.22 per cent. Owing to the indefinite character of the above statement, many prefer the second method of stating the results. In the above example, which represents about an average normal digestion, the acidity would be said to be 60. Some would call it 60 degrees, while others would say 60 per cent., meaning 60 per cent. of decinormal alkali solution required for neutralization. The second method is quite generally used, and is in most cases preferable.

Chemical Examination of the Gastric Juice.—The chemical examination of the contents of the stomach has, in recent times, become an important aid in the diagnosis of diseases of the stomach. The clinical examination of the stomach and its contents, for diagnostic purposes, generally includes an estimation of the rapidity of absorption, the motility, the reaction, and acidity of the gastric juice; the determination of the kind and amount of acids present; an examination for syntonin, albumose, and peptone; the determination of the digestive activity, and a microscopical examination of the stomach contents.

The stomach contents for examination are obtained as follows: The usual method is to administer to the patient, on an empty stomach, an ordinary dry roll and a definite quantity—say, 360 c.c., or about ⅔ of a pint—of fluid, either simple warm water or weak tea without milk or sugar. The roll should be of a tolerably uniform weight of about 35 gm., or 540 grs. Such rolls contain about 7 per cent. of proteids, 0.5 per cent. of fat, 0.4 per cent. of sugar, 52.5 per cent. of non-nitrogenous matter, and about 1 per cent. of ash.

The test-meal may consist of oatmeal or barley, cooked in water and flavored with a little salt, and a glass of water. About one hour after taking the test-breakfast the stomach-tube is inserted, and that which remains in the stomach is drawn off. The amount obtained should be about 40 c.c., or 1⅓ ozs. A greater variation than 15 to 20 c.c. in either direction should be regarded as pathological.

Method of Drawing Out the Contents of the Stomach for Chemical and Microscopical Examinations.—The contents of the stomach are usually drawn off about one hour after the person has taken one of the above test-breakfasts. This is accomplished by the stomach-tube, Einhorn's gastric bucket, or by causing the patient to vomit. The first of these methods is usually to be preferred. Place the patient in a sitting position, dip the rounded end of the elastic stomach-tube in warm water, hold it about six inches from its extremity, and, as the patient opens his mouth, pass it to the back of his throat, and ask him to swallow. As he does so, pass the tube gently but rapidly into the esophagus, and onward to the stomach. If the gastric contents do not run out as soon as the outer end of the tube is lowered, cause the patient to compress the abdomen and cough or retch, when it will cause the contents to run out.

Examination of Stomach Contents.—Observe the quantity, the consistency, color, amount of mucus, and odor. Note any fragments of former meals, if such be present, or fragments of gastric membrane or blood. Fragments of membrane should invariably be examined under the microscope, for evidences of organic disease. Filter the stomach-fluid, and preserve the solid portion for further examination. The following chemical tests should be carried out on the clear filtrate as soon as possible. The following order of tests will be the most convenient :

1. Reaction.
2. Qualitative test for free HCl.
3. Estimation of total acidity.
4. Estimation of free HCl, combined HCl, and acid salts.
5. Presence of lactic acid.
6. Total organic acids.
7. Presence of pepsin and its activity.
8. Presence of rennin or milk-curdling ferment.
9. Presence of starch, dextrin, and maltose.
10. Presence of proteids and their nature.
11. Microscopical examination of the sediment.

Reaction.—The normal reaction of gastric juice is decidedly acid, and the acidity is due to HCl, acid salts (H_2NaPO_4), and occasionally organic acids, or carbonic acid. Lactic acid is usually present after an ordinary meal, but after the oatmeal test-breakfast it is usually absent, except in carcinoma. There are two sources of lactic

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acid—one from fermentation of the contents, especially liable to occur when the motor function of the stomach is deficient and the food is retarded longer than usual ; the other, sarcolactic acid, introduced with meats and other articles of diet. Butyric and acetic acids are occasionally found in the stomach contents, due to these fermentations. The reaction of the fluid is determined with litmus paper. Unsized paper stained with other coloring matters may be used. The following table gives the coloring matters and reagents most frequently used in the examination of gastric fluid, with indications :

NAME OF COLOR.	SOLVENT.	COLOR WITH ACIDS.	COLOR WITH ALKALIES.	REACTS WITH :	DEGREE OF SENSITIVENESS.
Phenolphthalein, ...	Alcohol, 1 per cent.	Colorless.	Pink or Red.	All acids.	Very sensitive.
Congo-red, ...	Water, 1 per cent.	Blue.	Wine Red.	Free acids only.	HCl=0.1 in 1000. Lactic=0.2 in 1000.
Tropeolin, ...	Water.	Deep Red.	Yellow.	All acids.	HCl=0.3 in 1000.
Litmus, ...	Water.	Red.	Blue.	All acids.	Very sensitive.
Dimethyl-amido-azobenzol, .	Alcohol, 0.5 per cent.	Cherry Red.	Yellow.	Free mineral acids.	HCl 0.02 in 1000.
Alizarin-sulphonate of sodium,	Water, 1 per cent.	Yellow.	Violet.	Free acids and acid salts.	. .
Boas' Resorcin Solution, . . . [Resorcin, 5 gm. ; cane-sugar, 3 gm.; alcohol (95 per cent.), 100 c.c.]	Alcohol.	Pink.	Colorless.	Free mineral acids.	HCl 0.05 in 1000.
Gunzburg's Solution, ... [Phloroglucin, 2 gm.; vanillin, 1 gm.; alcohol (95 per cent.), 100 c.c.]	Alcohol.	Pink.	Light Brown.	Free mineral acids.	HCl=0.05 in 1000.

These coloring matters, when used to indicate the reaction of a liquid, are called **indicators.**

Some of them, as litmus, congo-red, dimethyl-amido-azobenzol, and benzopurpurin, are frequently used in the form of strips of filter-paper colored with the dye and dried. Litmus paper is reddened by all acids and acid salts. Congo-paper turns blue in presence of all free acids, and dimethyl-amido-azobenzol is reddened by free mineral acids only. By testing the filtered gastric contents successively with paper colored with these three colors, we may determine whether it be acid, with litmus ; whether the acidity be from a free acid, with congo-red ;

and whether from free HCl, with azobenzol-paper. When the congo-paper is blued by the solution, showing free acid, and the paper is warmed gently over a flame, the blue color is discharged when it is due to organic acids alone, but remains blue if it has been produced by hydrochloric acid. We may confirm the presence of HCl, if it is thought necessary, by the solution of Boas or that of Gunzburg. These solutions are used as follows:

A few drops of the solution are spread out in a thin layer upon a porcelain dish or slab, which is then gently heated, and a drop of the solution to be tested is allowed to flow across it, or a glass rod dipped in the solution is drawn across the plate. If free hydrochloric acid be present, a deep scarlet-red streak is developed. If the acid be very weak, no change is observed until the solution evaporates entirely to dryness: blowing on the dish will cause the red streak to appear more rapidly. With this test it is unnecessary even to filter the gastric con-tents. This test is not simulated by the proteids, nor is it interfered with by acid salts, if present in the usual proportions, nor by organic acids. Its delicacy is such that it shows 1 part of HCl in 20,000 parts of water. Gunzburg's solution undergoes deterioration on exposure to light, and should be kept in a dark place or in a black bottle, and frequently renewed. For this reason the resorcin solution is to be preferred.

Detection of the Organic Acids.—There are two lactic acids met with in the stomach—sarcolactic acid and fermentation lactic acid. Sarcolactic acid is formed in the stomach from meat taken as food; the other lactic acid may be formed by fermentation. A very simple and rapid test for clinical purposes is that of Uffelmann. Diluted solutions of ferric chloride turn canary-yellow in the presence of lactic acid. A still better solution is the following:

A few drops of a dilute neutral solution of ferric chloride are mixed with two drops of pure carbolic acid, and water added until the solution assumes a beautiful amethyst-blue color. A few drops of a 1 : 2000 solution of lactic acid instantly changes the color to yellow. The delicacy of the reaction is very great. Lactates, as well as free lactic acid, unfortunately, produce this yellow color. It is said that alcohol, sugar, and certain salts can produce the same color. The test becomes certain if we first extract the organic acid from the gastric contents with ether, and apply the test to the residue left on evaporating off the ether. Acetic and butyric acids can usually be detected by the odor. The odor of acetic acid is usually unmistakable. It may also be detected by the use of ferric chloride, with which it gives a red color. Butyric acid changes Uffelmann's reagent to a tawny, reddish color, and this only occurs

when it is present in over 5 parts per 1000.   Alcohol is found only in rare cases of yeast fermentation.

Total Acidity.—The acidity of the gastric contents during digestion is made up of free HCl, free organic acids, acid-albumins, consisting of a loose combination of HCl and organic acids with the proteids of the food, and acid salts, chiefly acid sodium phosphate, NaH_2PO_4.

The **quantitative estimation** of the total acidity is best accomplished as follows :

To 10 c.c. of the filtered fluid, accurately measured into a beaker, three drops of a one per cent. solution of phenolphthalein is added, and enough $\frac{N}{10}NaOH$ solution, accurately measured from a burette, to produce a permanent pink color.   After the addition of a few cubic centimeters of the decinormal soda solution, a light rose color appears, which should not be mistaken for the end reaction.   The final change of color is produced by a single drop of the alkali, and hence the addition should be made drop by drop near the end.   Near the completion of the test, each drop will produce a pink-red cloud as it falls into the liquid, which will disappear on gently mixing the contents of the beaker by a rotary motion.

Estimation of Free Hydrochloric Acid.—Many methods have been devised for the estimation of the free hydrochloric acid, some of which are complicated and troublesome, while others are comparatively simple and require little skill.   **Simplicity of manipulation, reasonable accuracy of results, and a small consumption of time are prerequisites' of a good clinical method.**

We shall omit complicated and tedious methods.   Töpfer's method of estimating free and combined HCl is simple and easy enough to be adopted as the best clinical method.   It requires three separate titrations, practised upon three portions of 10 c.c. each, using three different indicators.   Three portions of 10 c.c. are accurately measured into three small beakers.   In No. 1 phenolphthalein is used as an indicator, and the end reaction gives the total acidity, as described above.   In No. 2 dimethyl-amido-azobenzol is used as the indicator, which reacts only with free HCl.   In No. 3 alizarin-sulphonate of sodium is used as the indicator, which reacts with all the elements of the acidity except acid albuminates.   The total acidity is estimated in No. 1, the free HCl in No. 2 ; the combined HCl is found by deducting the number of c.c. used in No. 3 from that used in No. 1 ; and the organic acids and acid salts together are found by deducting the sum of the free and combined HCl from the result of the titration of No. 1.

The details of the above method are as follows:

The estimation of total acidity is described above (p. 595).

To the second portion of 10 c.c. three or four drops of a o 5 per cent. alcoholic solution of dimethyl-amido-azobenzol are added, and decinormal NaOH solution is run in from a burette until the color changes from red to a clear yellow. This color is very sensitive to mineral acids, and is not affected by combined HCl, acid salts, or by organic acids, unless the proportion of lactic acid reaches o. 2 per cent. or above.

When the estimation of organic acids to be described below requires the addition of three or more c.c. of decinormal NaOH solution for 10 c.c. of the fluid, it will be best to confirm the above by a titration with the resorcin solution of Boas, or the phloroglucin solution of Gunzberg.

The number of c.c. of decinormal NaOH solution used, multiplied by 0.00365, the weight of HCl neutralized by 1 c.c., gives the weight of free HCl in 10 c.c. This, multiplied by 10, gives the weight in 100 c.c. Or, the number of c.c. of NaOH solution multiplied by 10 gives the number of c.c. required by 100 c.c. of the filtrate.

The reagents of Boas and Gunzberg give the same indications, and are used in the same way:

To 10 c.c. of the filtrate from the gastric contents add $\frac{N}{10}$ NaOH until a drop of the solution, removed on the end of a glass rod and evaporated on a white surface with the resorcin solution, fails to give a pink color. A piece of white "milk glass" answers very well for this purpose. A few drops of the indicator are spread over the glass and dried at a gentle heat. In performing the titration, a drop of the solution is removed on a glass rod and drawn across the plate and the plate warmed over a naked flame. Blowing upon the streak as it evaporates hastens the appearance of the color.

Estimation of HCl in Combination with Proteids.—The first effect of gastric digestion upon the proteids is the formation of a small amount of acid-albumin. When the amount of HCl secreted is small, the proteids may combine with it and leave no free HCl. As long as enough of the acid is secreted to satisfy the affinities of the proteids and carry on this preliminary step in the digestion, the digestion may proceed in a fairly normal manner, even when no free HCl can be detected.

It is important, therefore, to determine the amount of this **combined HCl**, as well as the **free HCl.** This is especially important in cases of diminished HCl, **hypochlorhydria,** or total lack of free acids, **anacidity.** The combined HCl may be estimated by means of sodium alizarin-sulphonate as an indicator.

The third portion of 10 c.c. is then colored with three drops of a 1 per cent. aqueous solution of alizarin, and titrated with $\frac{N}{10}$ NaOH until a clear reddish-violet color is reached. This is reached when the free HCl, organic acids, and acid salts have been neutralized. The difference between the number of c.c. used in this titration and that used in estimation of the total acidity with phenolphthalein, gives the number of c.c. of $\frac{N}{10}$ NaOH used in neutralizing the combined HCl.

Owing to the difficulty of an inexperienced eye, in detecting the correct shade of violet in this titration, Töpfer recommends that a one per cent. solution of Na_2CO_3 be colored with the sodium alizarin-sulphonate solution, and this used for comparison, the color of this solution being imitated in the titration. The neutral tint is more nearly obtained in a one per cent. solution of sodium phosphate.

The above methods, after a little experience, give reliable results for clinical purposes, and require little skill in the manipulation.

The **estimation of the free and combined acids and acid salts** may be made by Leo's process. This process depends upon the fact that when pure precipitated chalk, $CaCO_3$, is added to the fluid, the free acids and acids combined with albumin are neutralized by the $CaCO_3$. The acidity remaining after this treatment is due to acid salts, and they may be estimated by this method. By removing the organic acids with ether and then applying the method, the free and combined HCl may be estimated.

Method.—Ten c.c. of the filtered gastric contents are shaken in a separating funnel with 50 c.c. of ether, which removes the organic acids; the liquid is then separated from the ether, returned to the separating funnel, and again shaken with 25 c.c. of ether and again separated from the ether. The fluid is then treated with 0.5 c.c. of a twenty per cent. solution of $CaCl_2$, and titrated with $\frac{N}{10}$ NaOH, using phenolphthalein as the indicator. The result gives the acidity due to acid salts plus the free and combined HCl. Another portion of 15 c.c. of the fluid is treated with about 1 gm. of $CaCO_3$, and filtered through a dry filter. To 10 c.c. of the filtrate add 5 c.c. of the $CaCl_2$ solution and titrate with $\frac{N}{10}$ NaOH with phenolphthalein. The result gives the acidity due to acid salts, which, deducted from the result obtained in the first titration, gives the free and combined hydrochloric acid.

The hydrochloric acid is greatly diminished or entirely absent in the acute stage of all fevers; in chronic gastric catarrh with atrophy of the gastric glands and amyloid degeneration of the membrane; in all cachectic states, chlorosis, certain nervous

troubles, many forms of poisoning, Addison's disease ; in cancer of the stomach, if it involves a considerable area or is attended with catarrh of the mucous membrane, which is usually the case.   It is absent, as a rule, in cancer of the stomach, and this fact is a valuable aid in the early diagnosis of this disease.

The Organic Acids.—The presence of a considerable amount of organic acids in the stomach contents after the usual test-meal is to be regarded as pathological.   The acids present may consist of lactic, butyric, or acetic acids.   Butyric acid can usually be detected by an odor like that of rancid butter.   Acetic acid will be detected by the odor of vinegar, especially on warming the fluid.   The detection of the organic acids is more certain when they are separated from the fluid by shaking them out with ether, allowing the ether to evaporate and applying the tests to the residue.   As lactic acid is likely to occur in larger amounts and more frequently than the others, several tests have been proposed for its detection.   Any pronounced quantity of organic acids is generally regarded as an evidence of pyloric stenosis, deficient HCl secretion, deficient motor power, or dilatation of the stomach—in other words, of an unusual delay of food in the stomach, with resulting fermentations.   When we desire to make a careful clinical test for lactic acid, it is best to give a test-breakfast of oat- meal or barley-gruel, in preference to Ewald's test-breakfast, as the former contains no lactates, while the latter may.

Uffelmann's test for lactic acid is conducted as follows :

Five drops of a strong carbolic acid solution are added to 20 c.c. of water, well mixed, and two drops of ferric chloride solution added, or enough to give a clear amethyst-colored solution.   This solution changes to a canary-yellow color, with but traces of lactic acid, or with gastric fluid containing it.

Quantitative Estimation of Organic Acids.—There are a number of such methods, but the most satisfactory is that of Hehner and Seemann, sometimes called Braun's method : Exactly neutralize 10 c.c. of the fluid with $\frac{N}{10}$ NaOH, and evaporate to dryness on a water-bath, in a platinum or porcelain basin.   When dry, the basin is heated over the lamp as long as the residue burns with a flame. The residue, after cooling, is extracted with boiling distilled water, filtered, and the filtrate titrated with decinormal HCl.   The titration is best done by adding a measured excess of the $\frac{N}{10}$ HCl, the solu- tion boiled to expel the carbon dioxide, and the excess of acid deter- mined with $\frac{N}{10}$ NaOH, using phenolphthalein as the indicator.   The difference between the number of c.c. of acid and alkali used will give the acidity due to organic acids present in the 10 c.c. of liquid

taken. The organic salts of sodium formed during the neutralizing of the liquid are changed by the ignition of the dry residue into sodium carbonate. The amount of sodium carbonate present in the residue which is estimated in this titration, is the measure of the amount of the organic salts formed. The above method leaves little to be desired as to accuracy and simplicity.

The Volatile Fatty Acids.—When it is desired to know the quantity of these acids present, they may be estimated as follows: Ten c.c. of the filtered gastric contents are evaporated on a water-bath to a syrup, made up again to about the original volume with pure water, and the acidity determined with $\frac{N}{10}$ NaOH, using phenol-phthalein as the indicator. The difference between the acidity here determined and the total acidity gives the volatile fatty acids. When lactic acid is known to be present by a qualitative test, the difference between the total organic acidity and the acidity due to volatile fatty acids may be taken to approximately represent the acidity due to lactic acid.

The Ferments—Pepsin.—The test for pepsin is accomplished by the addition of coagulated egg-albumin to the filtered gastric contents, and keeping this mixture at a temperature of about 40° C. (104° F.) for a definite time, and noting whether the albumin is corroded. If the gastric contents have been found by the above tests to be deficient in HCl, enough should be added to bring the quantity up to about two parts per thousand. In the absence of free HCl, pepsin may be absent, but there may be pepsinogen, which only needs the addition of HCl to develop the pepsin. It is best to make two tests in such cases—one of the original fluid, and another after adding two drops of diluted HCl (U. S. P.). Coagulated albumin discs, made by cutting the white of boiled eggs in thin flakes of uniform thickness and punching them out by means of a cork-borer or glass tube, and preserving in glycerin, are used for this purpose. The presence of **rennin** is best shown by carefully neutralizing 5 c.c. of the filtered gastric contents, and mixing this solution with an equal volume of carefully neutralized milk. If rennin be present, the milk is coagulated in fifteen minutes.

Digestion of Starch.—In normal digestion there is no free acidity after the usual test-meal for twenty to forty minutes. The salivary diastase continues its activity during this time, converting the starch into dextrin and maltose. At the end of one hour the greater part of the starch should be converted, and iodine should give no blue color. A reddish-violet color of a watery solution of iodine shows the presence of erythrodextrin. A blue or purple reaction

with iodine, in a fluid that has been in the stomach one hour, indicates faulty amylolysis, due either to decreased diastase in the saliva, decreased secretion of saliva, or excessive acidity of gastric contents.

Digestion of Proteids.—For a description of the changes produced in proteids during gastric digestion, the student is referred to part IV, under Albumoses and Peptones.

The following tests may be employed to show the progress of proteid digestion :

Native proteids, albumin, and **globulin** are precipitated by boiling the slightly acidulated solution.

Acid-albumin, or syntonin, is precipitated by carefully neutralizing the solution with decinormal sodium hydroxide. It is best to use phenolphthalein to show the neutrality, as the solution must be exactly neutral to precipitate the acid-albumin.

Primary albumoses may be precipitated from the solution, from which the native proteids and acid-albumin have been separated, as above, by saturating the solution with $MgSO_4$ or NaCl.

Secondary albumose (deutero-albumose) may be precipitated from the filtrate from the primary albumoses, as above, by saturation with crystals of $(NH_4)_2SO_4$.

To **test for peptones,** saturate a portion of the original fluid with $(NH_4)_2SO_4$, heat nearly to boiling, and filter. To the filtrate, when cold, add phosphotungstic acid, which precipitates peptone ; or apply the biuret reaction. Add to fluid an excess of NaOH or KOH and two drops of $CuSO_4$ solution. A rose-colored solution indicates peptone.

The rapidity of absorption from the stomach is tested by giving the person a capsule containing 0.2 gm. (3 grs.) of potassium iodide, and then testing the saliva at the end of each minute for the iodine reaction. **With a normal stomach, iodine appears in the saliva ten to fifteen minutes after giving the capsule.**

The iodine is detected in the saliva as follows : Strips of filter-paper are soaked in starch-mucilage and dried. One of these papers is pressed upon the tongue, removed, and then touched with a glass rod previously dipped in some yellow nitric (nitrous) acid. The appearance of a blue spot shows the presence of iodine. Some prefer to give other substances than potassium iodide. Some use a solution of common salt of known strength, drawing out what is left in the stomach after ten minutes, and estimating the salt left in the stomach. When the capsule is administered to an empty stomach,

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a delay in the appearance of the iodine reaction in the saliva to twenty minutes, or longer, indicates some serious organic disease of the gastric mucosa.

The motility or **motor function** of the stomach is a matter of importance, and its determination is sometimes required. When the motility is normal or increased, the food, even if it is not digested, is passed on into the duodenum before any disturbance arises from lack of digestion. The motor function may in this way compensate for lack of digestive power in the stomach. The lack of proper motor power, on the other hand, may produce dyspeptic symptoms where the digestive power is normal, because of the long delay of the food in the stomach, with secondary fermentations. Fleischer determines the motility of the stomach by giving a gelatin capsule containing o.1 gm. (1½ grs.) of iodoform, which drug is decomposed in the duodenum, and iodide of sodium formed, which is absorbed. Iodine can be detected in the saliva in from fifty five to one hundred minutes when administered after the usual test-breakfast.

Ewald's salol test is another chemical test of the motility of the stomach. Salol is nearly insoluble in the gastric juice, and does not enter the circulation until it is decomposed. It does not decompose until it reaches the duodenum, when it splits up into phenol and salicylic acid. The latter is then absorbed, and appears in the urine from sixty to seventy-five minutes after taking about o.6 to 1 gm. in a capsule. Or, we may note how long the salicylic acid continues to be eliminated by the urine. If the reaction shows the acid in the urine at thirty hours or longer, it may be regarded as proof of deficient motility of the stomach. Salicylic acid is easily detected in the urine by wetting a piece of filter-paper with this fluid and dropping on the moistened spot a drop of a ten per cent. solution of ferric chloride. The edge of the drop will assume a violet color in presence of traces of salicylic acid. These papers may be dried and preserved, if necessary, as records of the test. Klemperer pours 100 c.c. (3⅓ ozs.) of pure olive oil into the empty stomach, and removes with the stomach-tube what remains after two hours, to determine how much has been passed into the duodenum. There are several mechanical methods of testing the gastric peristalsis. They depend upon the pressure the stomach exerts upon an intragastric rubber bag attached to a manometer or other recording apparatus.

Examination of the Sediment or Solid Particles Obtained from the Stomach.—The quantity, character, and appearance of the insoluble portions of gastric contents are important. We may in this way find particles of food eaten twelve to twenty-four hours before, showing a probable dilatation of the stomach or stenosis of the pylo-

rus. Excess of the starchy elements of the food indicates an excess of gastric acidity, or a deficiency in the activity of the saliva; while an absence of bread or starch and the presence of proteid articles of diet indicate deficient acid. These indications will, of course, be more marked after an ordinary meal than after the usual test-meal. An examination of vomited matters will often reveal the above indications. The presence of mucus, in excessive amount, will be evident to the eye by its stringy, tenacious character. We may demonstrate its presence, chemically, by shaking the sediment with a weak solution of NaOH, filtering, and acidifying the filtrate with acetic acid, when the mucus will be precipitated. Excess of mucus is found in gastritis and gastric catarrh. Biliary coloring matters are usually evident to the naked eye, or they may be demonstrated by Gmelin's test (see chapter on Urine), or with the spectroscope. Blood may be detected with the unaided eye when present in considerable quantity. When in small quantity, we may use the spectroscope or the guaiac and turpentine test, mentioned under Urine. The microscope, however, will usually render these tests unnecessary.

Microscopical examination should always be made of the sediment obtained from the stomach. Besides fragments of undigested food, we may recognize the staining of these particles by bile, the presence of yeast-cells, blood-corpuscles, sarcinæ, and bacteria of various kinds. It is best to first examine the sediment unstained, and then stained with Bismarck brown or Lugol's solution, and then with methyl-blue, which last color will reveal the bacteria to the best advantage. Bacteria of various kinds are always to be found in the stomach, and are only indicative of disease when present in very large numbers. An unusually long non-motile bacillus, first recognized by Oppler, is found in most cases of gastric carcinoma. It has the power of rapidly changing sugars to lactic acid, and in carcinoma of the stomach the number of bacilli increases with this acid. Its absence in gastric disease is a very strong argument against a diagnosis of cancer. Excessive bacterial fermentations in the stomach usually give rise to dyspeptic symptoms, such as distention, pain, delayed or difficult digestion, disturbed intestinal peristalsis, toxic absorption, etc.

The Pancreatic Fluid.—The pancreatic fluid is the secretion of the pancreas poured out into the duodenum at the junction of the middle and lower third of the duodenum, through the pancreatic duct. In some lower animals there are two ducts. The rabbit, dog, and cat each have two ducts. The pancreatic juice is a transparent, colorless, odorless, saltish, alkaline fluid, effervescing with the acids. It is composed of water 90 per cent. and of solids 9.93 per cent. There are few cells, if any, in suspension, and it is, therefore, clear.

The pancreatic fluid has at least three ferments, or zymogens that furnish at least three ferments—the diastasic ferment, **amylopsin**, allied to, if not identical with, ptyalin ; **tripsin**, a peptone-forming ferment ; **pialin**, a saponifying ferment ; and **rennin**.

The secretion of the pancreatic juice begins as soon as food is taken, increases for two hours, then falls, and a second rise takes place in from five to six hours, when it falls again until about the eighteenth hour, if no more food be taken. The most marked characteristic of the pancreatic secretion is that it acts in neutral or alkaline solutions better than in acid solutions. A slight excess of HCl destroys it entirely. Its most marked action is upon proteids and starches, converting the former into peptone, with certain side-products, and the latter into maltose, which is afterward rapidly changed into dextrose. Pancreatic digestion differs from peptic digestion in certain well-marked features, which are shown below :

ACTIVE PEPSIN (ACID MEDIUM).	PANCREATIN (ALKALINE MEDIUM).
Fibrin swells before dissolving.	Fibrin corroded away.
Assisted by HCl.	Assisted by Na_2CO_3.
Destroyed by Na_2CO_3.	Destroyed by HCl.
Forms syntonin, albumose, and peptones.	Forms alkali-albumin, antipeptone, hemipeptone, leucin, tyrosin, hypoxanthin, and aspartic acid.
Acts best on albumin.	Acts best on fibrin.

The pancreatic fluid is the chief digestive fluid concerned in the complete digestion of starch. It contains the ferment **amylopsin**, or **pancreatic diastase**, which readily converts starch into maltose, and finally into dextrose. The extract of the pancreatic gland is exceedingly active in its effect upon cooked starch. This secretion in the new-born is destitute of amylopsin, which makes its first appearance at about the end of the second month. Previous to this time, infants can not usually digest starch. Some infants, however, seem to be endowed with the property of digesting starch, and it would seem, therefore, that they must secrete some diastase, either in the saliva or the pancreatic fluid. The milk-curdling property of the pancreatic fluid is less marked than in the case of the gastric fluid. Of the fat-splitting ferment little is known, except that a special ferment exists in the pancreatic juice which has this property. It decomposes lecithin into neurin, and saponifies fats to a slight extent only, but sufficiently to assist in the formation of a perfect emulsion. A small amount of free acid in the oil greatly assists its emulsification with a diluted solution of sodium carbonate. For this reason a slightly rancid oil emulsifies more readily than a neutral oil.

The succus entericus is the digestive fluid secreted by the glands of the intestinal mucous membrane, principally by Lieberkuhn's and Brunner's glands. The secretion from Brunner's glands contains proteids, mucin, and ferments. It dissolves proteids, slowly changes starch into sugar, changes maltose into dextrose, and inverts cane-sugar. It is a light-yellow, opalescent, strongly alkaline fluid.

The succus entericus is most active in the dog. Its diastasic power is less than that of the saliva or the pancreatic fluid, and when it acts upon starch it forms dextrose instead of maltose. The large intestine contains none of this ferment.

The Bile.—The bile is a viscid, transparent, golden-yellow colored liquid secreted by the liver. It has a bitter taste and an alkaline reaction. Specific gravity, 1009 to 1020. Its composition is highly complex, but is represented principally by the following :

	PER CENT.		PER CENT.
Water,	91.68	Soaps,	1.39
Mucus and pigment,	0.129	Fat,	0.73
Glycocholate of sodium,	3.03	Lecithin,	0.53
Taurocholate of sodium,	0.87	Cholesterin,	0.35

The amount of bile secreted in twenty-four hours is variously stated at from 1000 to 1700 gm., or from twenty-three to forty-seven ounces. The bile is prepared in the liver from the large amount of blood received by it. More is secreted during digestion than during fasting, and the percentage of solids increases during digestion. In abstinence from food, or with a fatty diet, little is secreted ; more is secreted with bread and rice, still more with meat, but most with a mixed diet. The bile is stored in the gall-bladder when not needed, and poured into the duodenum near the point of exit of the pancreatic duct. On standing, the bile becomes of a brown-yellow color and readily undergoes decomposition.

The constituents of the bile are described elsewhere.

The functions of the bile are :

First. To assist in emulsifying fats, and, in the presence of the pancreatic juice, it assists in saponifying a small portion.

Second. It readily wets the mucous membrane, dissolves fats, and it assists in their absorption.

Third. Checks putrid fermentation in the intestines.

Fourth. It precipitates the pepsin, syntonin, albumoses, and peptones from the chyme, and stimulates the production of intestinal juice.

Fifth. It contains a diastasic ferment which converts starch into sugar.

Sixth. The bile stimulates the contractions in the muscular coat of the intestines and villi, increases the moisture in the intestine, acts as a lubricant, and favors the passage of the contents of the small intestine.

A considerable portion of the bile is re-absorbed, a part of the coloring matter, at least, being excreted by the kidneys, while a part passes out with the feces. The biliary acids are mostly absorbed from the ileum and jejunum, only a trace being found in the feces.

Toxic Effects.—Obstruction to the discharge of the bile leads to its absorption by the lymphatics, giving rise to cholemia, or absorptive jaundice. The coloring matter passes into the circulation and stains the tissues yellow. The effect of the absorption of bile is to produce a slow pulse and respiration, low temperature, irritation of the skin, lassitude, headache, and coma.

THE FECES.

Chemical Composition of Feces.—An adult, upon a mixed diet, passes about 120 to 180 gm. (or 4 to 6 ozs.) of moist excrement in twenty-four hours. A vegetable diet increases the amount. If much indigestible food be taken, it may be as much as 500 gm. The consistency depends upon the amount of water present, which is usually about from 68 to 80 per cent. A pure flesh diet gives a comparatively dry feces, while substances rich in sugar yield feces with a comparatively large amount of water. The quantity of water taken has no influence upon that found in the feces. The water in the feces seems to be in direct ratio with the energy of the peristalsis.

The feces of adults have a neutral, sometimes alkaline, and rarely acid reaction. The alkalinity is derived from the ammoniacal fermentations, while the acidity is from lactic and butyric acid fermentations. Acetic and propionic acids have also been found in the feces. The copious secretion of mucus favors the occurrence of the neutral or alkaline reaction. The feces of infants fed upon milk are usually acid from the presence of lactic acid and free, fatty acids.

The color of feces depends upon the amount of altered bile-pigment mixed with them, to which the bright-yellow to dark-brown color is due, or upon the character of the food. The normal yellow-brown coloring matter of feces is hydrobilirubin. If much blood be present,—that is, after hemorrhages,—the feces are brownish-black from hematin. Preparations of iron, bismuth, or lead, taken by the mouth, color the

feces black from the formation of the sulphides of these metals. Some green vegetables impart a brownish-green color, due to chlorophyll. The green color of infants' feces is believed to be due to butyric and lactic fermentation, and to the action of these acids upon the biliary coloring matters. In adults green passages may be due to a green microscopic plant, or **chlorococcus.**

The disagreeable odor of normal feces is due in great part to indol and skatol. These are products generated by the putrid bacteria, and come from the decomposition and transformation of albuminoid matters. Hydrogen sulphide, and sometimes a trace of hydrogen phosphide, ammonia and organic bases contribute to the odor of fecal matter.

The feces contain : First. Alimentary substances which are assimilable, but which have been taken in excess, as starch, fatty matters in notable quantities, and a small proportion of non-assimilable proteids.

Second. Indigestible substances, such as vegetable fiber, celluloes, chlorophyll, gums, pectic substances, resins, elastic tissue, epidermic tissue, tendons, diverse coloring matters, nuclein, chittin, insoluble salts (silicates, insoluble sulphates, ammonium-magnesium phosphate, and calcium phosphate).

Third. Products coming from the digestive tube itself ; intestinal mucus, epithelial cells, biliary acids (in traces), cholesterin, and bacteria.

Fourth. Substances which failed of absorption, as emulsified fats, the free fatty acids, leucin, and bilary coloring matters.

Fifth. Decomposition products due to microbic action, as the free fatty acids from acetic up to palmitic, this last quite abundant ; also butyric, isobutyric, and lactic acids, phenol, cresol, indol, skatol, stercorin, excretin, ammonium carbonate and sulphide, amins, amids, ptomaines, leucin, tyrosin, and phenylpropionic, phenylactic, and parahydroxylphenylactic acids. Some of these bodies, especially the ptomaines, acids, phenols, and coloring matters, are partly absorbed, the phenols passing into the urine in combination with sulphuric acid, as sulphuric ethers.

Sixth. Pigments. The pigments found are stercobilin, hematin, biliary pigments, hydrobilirubin, and food-coloring matters.

The following figures give the analysis of 1000 parts of fresh excrement :

	ADULT MAN.	INFANT.
Water,	733	851.3
Fixed solids,	267	148.7
Total organic matter,	208.75	157.1
Mineral matter,	10.95	13.6
Alimentary residue,	83	. . .

The analyses of excrement have their importance, principally, as a guide to the assimilation or malassimilation of food, and also because the excrement of various animals is employed as a fertilizer. The meconium, or the residue which accumulates in the intestinal canal during fetal life, and which is passed soon after birth, contains bilirubin and biliverdin in abundance ; also biliary acids, some fatty acids, the alkaline sulphates, chlorides, and the phosphates of calcium and magnesium. It does not contain urobilin, glycogen, peptone, lactic acid, leucin, or tyrosin. Two peculiar substances are found in feces which do not occur elsewhere in the body. These are **excretin** ($C_{20}H_{36}O$) and **stercobilin,** or **serolin. Excretin** may be obtained from the feces by making an alcoholic extract and keeping it for a considerable time at a temperature below o° C. (32° F.), when there is deposited an olive-colored, granular body, having a fecal odor and acid properties, from which Marcet has named it **excretolic acid.** It resembles cholesterin in its properties.

Meconium is the name given to the dark, greenish-brown, pitch-like contents of the intestine of a human fetus at birth. It is devoid of fecal odor and has an acid reaction. The microscope shows it to contain cylindrical cells from the villi, often grouped together as when covering the villi. They are usually stained green. Besides these epethelial cells, there are cholesterin plates, fat globules, and crystals of bilirubin. Meconium contains mucin, bilirubin, biliverdin, biliary acids, cholesterin, traces of fat, and fatty acids. It contains from 20 to 28 per cent. of solid matter. These feces of infants fed with normal breast-milk are lemon-yellow to orange-colored, and contain about 85 per cent. of water, 13.5 per cent. of organic and 1.5 per cent. of mineral matter. On shaking up with water, the water becomes acid, and numerous flocculi of larger or smaller size separate.

These flakes of solid matter consist of fat, fatty acids, and lactate of calcium, with usually a very small amount of casein and epithelium cells. In some cases, the fat and fatty acids will comprise as much as 50 per cent. of the total solids, although usually it is about 1.4 per cent. of the total feces. Mucin, biliary coloring matters, and micro-organisms are usually found. While the undigested casein is usually small in amount, in infants nursed at the breast, it is usually much greater in infants fed upon cows' milk. Frequently, large masses of casein and fatty acids are seen.

Changes in the Feces in Disease.—The feces of adults become a blue-clay or light gray color, when the bile is shut off from the intestine, very fetid, and contain a large quantity of fat. Occlusion of the pancreatic duct also leads to the appearance of fat in the stools. Diarrheal stools, or stools after purgative medicines, vary from the

normal principally in the proportion of water, although the rapid peristalsis will usually bring down more or less undigested matters. The feces in typhoid fever are usually semifluid, and frequently contain blood and small portions of necrotic membrane, and usually contain crystals of ammonium-magnesium phosphate. They contain the Eberth bacillus, peculiar to this disease, and a poisonous base known as typhotoxin, having the formula $C_7H_{17}NO_2$, and an active toxalbumin. The Eberth bacillus decomposes cane-sugar, with the production of levorotatory lactic acid. The stools of **cholera** are thin and almost colorless, resembling rice-water. Under the microscope are seen a large number of epithelium cells from the villi, and bacterial analysis reveals the comma spirillum. Cholera stools contain indol and nitrites, and develop a blood-red color on adding dilute sulphuric acid, due to the formation of nitrate of nitroso-indol. This reaction is often used for diagnostic purposes. Poisonous bases and toxalbumins have also been found.

Dysenteric stools are characterized by an abundance of mucus tinged with blood, peculiarly fetid, and frequently containing fragments of sloughing mucous membrane. Microscopical examination sometimes reveals an ameba, known as the **ameba coli,** characteristic of certain cases of tropical dysentery. The stools of hemorrhages into the stomach, or elsewhere along the digestive tube, are darkbrown or black in color, and very fetid. **Gall-stones** are sometimes found in feces, as well as small calculi, or **enteroliths.** These bodies are best seen by thoroughly washing the feces in water, and pouring off the top liquid with the lighter floating particles, when the gall-stones or concretions, if present, will be found in the bottom of the vessel. **Animal parasites** of various kinds or their eggs, and even larvæ of insects are sometimes found in feces. Seeds of fruits, fragments of stone, metal, or other accidental substances will occasionally find their way into the feces.

Intestinal Gases.—The large and small intestines always contain more or less gas. This is usually a mixture of carbon dioxide, methane, nitrogen, and hydrogen. In strictly normal digestion, unless substances rich in sulphur are eaten in considerable quantities, sulphuretted hydrogen is not found in the gases of the colon. The CO_2 is derived in part from bacterial decomposition of carbohydrates and proteids, and in part from the blood. The CH_4 is derived from the bacterial decomposition of carbohydrates and proteids, but especially from cellulose. The nitrogen is partly derived from the blood, partly from the air swallowed, and partly from decomposition of proteids. The hydrogen is derived from fermentations of carbohydrates and proteids. Butyric fermentation of sugars generates

hydrogen. The following table gives the percentage composition of the gases of the large intestine, as given by Ruge :

VOL. IN 100 VOLS.	MILK DIET.		MEAT DIET.			LEGUMINOUS VEGETABLE DIET.		
	I.	II.	I.	II.	III.	I.	II.	III.
Carbon dioxide, . . .	16.8	9.9	13.6	12.4	8.4	34	38.4	21
Hydrogen, ...	43.3	54.2	3	2.1	0.7	2.3	1.5	4
Marsh-gas, ...	0.9	. .	27.5	27.5	26.4	44.5	49.3	55.9
Nitrogen, ...	38.3	36.7	57.8	57.8	64.1	19.1	10.6	18.9

MILK.

Milk is the secretion of the mammary glands, the presence of which is characteristic of the mammalia. The milk of different animals differs somewhat in composition, but always contains the same constituents. It contains all the necessary constituents of a perfect food, and is intended for the nourishment of the young until they are able to live upon other foods. Milk is an opaque, white fluid, containing fat globules in suspension, albumin, sugar, and salts in solution, and caseinogen in partial solution. The reaction of human milk is generally feebly alkaline ; that of the cow is usually neutral or faintly acid, while that of the carnivora is generally acid. Milk readily becomes acid or sour on exposure to the air, due to lactic fermentation. Microscopical examination reveals the fat in a state of perfect emulsion, the fat globules remaining suspended and separate from one another. The fluid seen between the globules is not perfectly clear, but contains small granules of caseinogen, which may be filtered out by passing it through a clay filter. The milk which is secreted for the first few days after parturition is viscid, yellow in color, of high specific gravity, and shows the presence of a few corpuscles of a peculiar character. These corpuscles seem to be epithelium cells containing fat globules, which they have not yet liberated. These cells are called **colostrum corpuscles,** and the milk of the first few days of lactation is called **colostrum.** The composition of colostrum varies in different individuals. The total solids vary from 13 to 15 per cent. ; the casein, 1.5 to 3 per cent. ; albumin and globulin, 1 to 7 per cent. ; sugar, 3 to 6 per cent. ; and salts, 0.3 to 0.5 per cent. It is believed by some that each fat corpuscle is surrounded by a shell, or membrane, of casein. Others deny the existence of this membrane.

The **specific gravity** of milk is usually determined with the hydrometer. The specific gravity of cows' milk varies from 1029 to 1035. An excess of fat lowers the specific gravity and the removal of fat raises it. The addition of water will lower the specific gravity. These facts are made use of for the detection of the ordinary adulterations of milk.

The amount of milk secreted varies with the health of the animal, the amount of food taken, and various other conditions. The amount secreted by a woman each day is about 1 liter. A good cow secretes about 7 to 10 liters. The composition of milk varies in different classes of animals with the state of nutrition of the animal, the constitution, the age, the period of lactation, and the character of the food.

Composition of Milk.—The published analyses of milk are very numerous, and the older analyses, made by older methods, differ somewhat from the analyses made by more recent methods. The comparative composition of human milk and of cows' milk is given in the following table:

ANALYSIS OF HUMAN MILK AND COWS' MILK.—(*König.*)

		Woman's Milk.			Cows' Milk.	
	MEAN.	MINIMUM.	MAXIMUM.	MEAN.	MINIMUM.	MAXIMUM.
Water, . . .	87.29	83.69	90.90	87.41	80.32	91.50
Total solids, .	12.71	9.10	16.31	11.59	8.50	19.68
Fat, ...	3.78	1.71	7.60	3.66	1.15	7.09
Milk-sugar, .	6.04	4.11	7.80	4.92	3.20	5.67
Casein, . . .	1.03	0.18	1.90	3.01	1.17	7.40
Albumin, . .	1.26	0.39	2.35	0.75	0.21	5.04
Albuminoids,	2.29	0.57	4.25	3.76	1.38	12.44
Ash, ...	0.31	0.14	(?)	0.70	0.50	0.78

Besides the constituents mentioned in the table, milk also contains very small quantities of certain extractives, among which are creatin, leucin, the odoriferous principle, lecithin, nuclein, etc. It also usually contains certain gases, principally carbon dioxide, oxygen, and nitrogen. Colostrum contains a larger proportion of solid matter than ordinary milk, a larger amount of proteid materials, and less sugar.

The following table shows many differences between human and cows' milk not shown in the above table, and which are of importance in adapting the latter to infant feeding:

TABLE SHOWING DIFFERENCES BETWEEN HUMAN AND COWS' MILK.

Properties.	Human Milk.	Cows' Milk.
Physical appearance.	Bluish, translucent, odorless, sweetish.	Opaque, white or yellowish-white, distinct odor, feebly sweet taste.
Specific gravity.	1026 to 1036.	1029 to 1035.
Reaction.	Amphoteric or slightly alkaline.	Amphoteric or slightly acid; becomes quickly acid on exposure to air.
Behavior on boiling.	Does not coagulate, and forms a very slight pellicle, scarcely observable.	Does not coagulate, but forms a distinct pellicle of casein and lime-salts.
Spontaneous coagulation.	Coagulates only after one to two days, at room-temperature.	Coagulates after six to twelve hours at room-temperature; due to lactic acid.
Coagulation with rennet.	Coagulates incompletely in small, isolated flocculi, never forming visible curds.	Coagulates at body-temperature, separating into curdy masses and opalescent whey.
Fat.	Butter yellowish, similar to cow-butter; sp. gr. at 15° C.＝0.966; melts at 34° C.	Butter yellow-white; sp. gr. at 15° C. ＝0.949 to 0.996; melts at 35.8° C.
Composition of fat.	Olein, palmitin, stearin, butyrin, caprin, caproin, myristin.	Olein, palmitin, stearin, caproin, caprylin, caprin, laurin, myristin, arachin, butyrin, lecithin, cholesterin.
Relation of acids.	Volatile acids relatively small; oleic acid, one-half non-volatile acids.	Volatile acids relatively large, oleic acid small, palmitic and stearic large.
Caseinogen.	Precipitated with difficulty by salts and acids; easily soluble in acids; leaves no pseudonuclein with peptic digestion.	Precipitated easily by salts and acids; precipitate not easily soluble in excess of acids; leaves residue of pseudonuclein.
Composition of proteids.	Lactalbumin, lactoglobulin, and casein; ratio of casein to albumin, 1 to 1.2 (?).	Lactalbumin and globulin small; casein to albumin, 1 to 7, or even 1 to 10.
Mineral matters.	Relatively small amount; contains one-sixth as much CaO and one-fourth as much P_2O_4 as cows' milk.	Contains relatively large amount.
Nuclein and lecithin.	Nuclein, 1.2 gm. per liter (Siegfried); lecithin, 1.7 gm. per liter (Stoklasa).	Nuclein, 0.6 gm. per liter (Siegfried); lecithin, 1 gm. per liter (Stoklasa).
Bacteria.	Generally sterile; rarely staphylococcus albus and aureus.	Contains numerous bacteria, and occasionally typhoid, diphtheria, tubercular organisms, etc.

The proteids which occur in milk are probably three in number—caseinogen, lactalbumin, and lactoglobulin. Lactoprotein and peptone have also been described by some observers. When milk is allowed to stand at the ordinary temperature, a part of its lactose is converted by fermentation into lactic acid. When this has accumulated to a considerable extent, the caseinogen is precipitated. When milk is treated with rennin, or gastric juice containing this ferment, the caseinogen is rapidly converted into casein, and at the same time coagulation or precipitation occurs. When rennet is added to cows' milk, the result is a coherent clot or curd and a clear, yellowish fluid called whey. The curd contains the fat entangled with the casein. The whey contains the albumin, sugar, and salts. In human milk the curd is formed of smaller flocculi, and the same appearance may be produced with cows' milk if it is previously boiled or largely diluted with lime-water. Caseinogen is often compared to alkali-albumin ; the latter, however, does not coagulate with rennet, and is readily soluble in acids, while caseinogen is not. Caseinogen somewhat resembles the globulins in its behavior with neutral salts. The globulins, however, coagulate when heated, while caseinogen does not.

Casein.—This name is sometimes restricted, as above, to the proteids formed, by the action of rennet and acids, from the caseinogen of milk. Casein is the chief constituent of cheese.

Lactalbumin.—After the precipitation of the casein by acetic acid, this proteid is left in the solution. The scum which forms on the top of milk on boiling is probably formed by the coagulation of a part of the lactalbumin and caseinogen.

The boiling of milk before it is used as food is advantageous, in that all germs of disease are destroyed, and that the rennet gives a flocculent instead of the heavy, curdy precipitate. The lactalbumin is modified by the boiling, and precipitates on adding acid to the cold boiled milk.

Lactoglobulin.—Various observers have discovered other proteids than the two mentioned above. Lactoglobulin, whey proteid, lactoprotein, proteoses, peptones, and nuclein have been mentioned as occurring in milk, but our knowledge of the amount present is so slight that we will pass them with the mere mention. It is claimed by some that their supposed presence is due to faulty methods of examination. The lactoglobulin has the property of liquefying cooked starch and of partially digesting it. This property is destroyed by sterilization.

Fat.—The chemical composition of milk-fat is very nearly like that of adipose tissue, with small quantities of the triglycerides of butyric, caproic, caprylic, myristic, and arachinic acids. Milk also contains minute quantities of lecithin, cholesterin, and yellow lipochrome.

Cream is simply the upper layers of milk which has been left to stand, and in which the fat globules are more numerous than in whole milk. The amount of cream that will separate from the milk in twenty-four hours is sometimes made use of as a test for the richness in fat. A fair market milk will give from 10 to 12 per cent. of cream, while rich milk will frequently give from 15 to 20 per cent., or even more.

Butter is the fat of milk in which the fat globules are separated from the other constituents by mechanical agitation in the churn. About one-sixth of the fat remains in the buttermilk. Buttermilk contains, therefore, about from 0.5 to 1 per cent. of fat. Butter also contains small quantities of casein and lactose. Butter from human milk is richer in fluid fats than that made from cows' milk. By exposure to the air butter becomes rancid, due to the saponification of some of the glycerids of the fatty acids.

Milk-sugar, as will be seen in the above table, occurs to the extent of about 4.5 per cent. in cows' milk and about 6 per cent. in human milk. The characteristics of this sugar have been described in part v.

The **salts** of milk are the phosphates of potassium, sodium, calcium, and magnesium, with chlorides of potassium and sodium, and a trace of iron, which is in combination in the nuclein. The most of the phosphorus of human milk and about one-half that of cows' milk exist in organic combination in the nuclein and lecithin.

Sterilized and Pasteurized Milk.—Owing to the ease with which milk undergoes the lactic fermentation and becomes sour, various methods have been tried to preserve milk for use in large cities. Subjecting the milk to a low temperature has been in use for a long time, and is of great service. Milk kept at a temperature of about 10° C. (50° F.) will keep sweet for a number of days.

For use as a food for infants, this has been found to be impracticable. Even with the greatest precaution, the lactic ferment will slowly progress and will grow in such abundance, as soon as the food is taken, as to disturb the child's digestion. This may be and often is prevented by heating the fresh milk to 100° C. (212° F.) for fifteen to twenty minutes in a bottle or jar, closing it while hot, and excluding air until needed. This "**sterilized milk**" is to be found in the markets. It has not met with the success in use that was at first expected. The heat coagulates the lactalbumin, the globulin, and modifies the casein. On acidifying sterilized milk all the proteids are precipitated at once in a firm curd that is not easily digested, but appears in the feces. Experience shows that children fed upon this milk do not thrive as well as when fed on raw milk.

The nuclein and lecithin of the milk are decomposed at a tempera-

ture of 100° C. (212° F.), and this probably alters its nutritive qualities and accounts for the tendency of children to become rachitic when fed exclusively upon sterilized milk or condensed milk.

The temperature at which the above changes in the proteids begin is about 75° C. (167° F.). If milk is heated to about 68° C. (155° F.), or not above 70° C. (158° F.), many organisms are killed, and others so weakened that the keeping quality is greatly improved, without altering the taste or composition. This process is called **Pasteurization,** and is now used to preserve milk for use as food for infants.

Modified Milk.—By this term is meant cows' milk that has been changed in composition so as to resemble the composition of human milk. As the caseinogen of cows' milk is about three or four times that of human milk, and the albumin is but half that of human milk, there is a very decided difference in the digestibility of the two. Rennin coagulates the caseinogen only. The curd formed in the stomach from cows' milk is more abundant, and forms tough masses, difficult to digest, while that from human milk is slight in amount and flocculent.

The sugar of cows' milk is present in about 4.5 per cent., while that of human milk is nearly 2 per cent. higher. These and other differences in composition and behavior of the two milks, shown in the table on page 611, make it necessary to modify the composition of cows' milk for the successful nourishment of infants. Various methods have been proposed for accomplishing this, and have led to the production of numerous preparations put upon the market as baby-foods.

One of the most successful of the attempts to modify cows' milk to imitate human milk is a mixture of milk, cream, water, lime-water, and milk-sugar, made to correspond to the average analysis of human milk, and the mixture Pasteurized. Such mixtures are now to be had in many large cities from **milk laboratories,** established for the purpose of furnishing them. Milk of any desired composition may be ordered from the laboratory, and this composition may be changed at will.

The milk used for this process, as well as the cream, must be fresh, and the cream should be of nearly constant composition. The only way to secure this is to use cream separated by the centrifugal machine.

With such a cream, containing 20 per cent. of fat, the following proportions will give very nearly the composition of average human milk :

Milk,	2 parts ;	or, Milk,	4	fluidounces.
Cream,	3 parts ;	" Cream,	6	fluidounces.
Water,	10 parts ;	" Water,	20	fluidounces.
Lime-water,	1 part ;	" Lime-water,	2	fluidounces.
Milk-sugar,	½ part ;	" Milk-sugar,	7	drachms.

The analysis of this mixture will give about the following results, when a good milk is used :

Water, . . . 88.42	Fat, ... 4	Sugar, ... 6.26
Solids, . . . 11.58	Proteids, . . . 1.11	Ash, ... 0.21

Such mixtures can not be regarded as very near imitations of human milk. Even when the mixtures are made at milk laboratories, certain peculiarities of human milk, shown in the comparative table on page 611, can not be imitated in this way. The fat of the two milks are of different composition, and the process of centrifugal separation of the cream partially destroys the emulsion, and collects the fat globules into small masses and renders the fat less easily digested. The different amounts of nuclein and lecithin in the two milks are unfavorable to cows' milk, as regards its nutritive qualities. It is in the relative proportion of the two proteids that the most difficulty is experienced. The above mixture contains 1.11 per cent. of proteids, of which 0.86 per cent. is caseinogen and 0.25 is albumin and globulin. Human milk usually contains slightly more albumin than caseinogen, a fact that is of great importance in the behavior of the milk with rennin or with acids—*i. e.*, in the first stages of digestion. This relation between the caseinogen and albumin determines more than any other factor the character of the curd produced on coagulation. The larger the proportion of albumin to the caseinogen, the finer the flocculi formed. The actual amount of proteids in human milk varies at different periods of lactation, being greatest during the first week. The following figures show this variation, and the relative percentage of albumin and caseinogen (Camerer) :

PERIOD OF LACTATION.	TOTAL PROTEIDS.	CASEIN.	ALBUMIN AND GLOBULIN.
Eighth to eleventh day, ... 2.53		0.91	1.62
Twentieth to fortieth day, ... 1.74		0.55	1.19
Two to three months, ... 1.46		0.46	1.00
Eight months, ... 1.19		0.35	0.84

From the above analysis we see that the amount of total proteids in human milk during the first two weeks of lactation is about 2.5 per cent., and in many cases 3 per cent.; but of these nearly two-thirds are soluble albumin and globulin instead of caseinogen. We may increase the albumin in the above-described mixture by the addition of egg-albumin in the proportion of the white of two eggs to the quart of mixture. Assuming that the white of an average egg will weigh 30 gm., or 1 oz., and that it contains 12.2 per cent. of albumin, the whites of two such eggs would contain 7.32 gm. of albumin, and would add approximately 0.75 per cent. of egg-albumin to the above

mixture, and give 1.86 per cent. of proteids, of which 0.86 per cent. will consist of caseinogen and 1 per cent. will consist of albumin. While egg-albumin differs materially from lactalbumin, the physical behavior of the mixture is more nearly like that of human milk, and experience shows it to be well suited for infant nutrition.

A rational method of modifying cows' milk for use as an infant food is the following : The milk should be allowed to stand in a cool place for three or four hours, to allow the cream to separate. When the milk is received in bottles, as is the custom in large cities, this will be unnecessary. Siphon off from the bottom of the containing vessel two-thirds of the milk, leaving the cream and upper portion of milk undisturbed. This may be easily done with a small rubber tube, previously filled with water to start the siphonage. To the milk thus drawn off add a teaspoonful and a half of essence of pepsin or liquid rennet, warm to blood heat, 37° C. (98.6° F.), and keep at or near that temperature for twenty to thirty minutes, or until the curd separates. Then warm, with vigorous stirring, to 68° C. (155° F.) and filter, while hot, through muslin. This whey will contain approximately 1 per cent. of fat, 4.5 per cent. of sugar, 0.8 per cent. of soluble albumin, and 0.7 per cent. of salts. When cold, this whey is added to the rich milk left in the containing vessel.

The mixture thus obtained will contain approximately 1.2 per cent. of caseinogen, 0.8 per cent. of albumin, 4.5 per cent. of sugar, 3 per cent. of fat, and 0.7 per cent. of salts. To a quart of this mixture we must add 1.5 per cent. of milk-sugar to bring the percentage of this constituent up to 6 per cent. This will require about one-half ounce, or a heaping tablespoonful, of powdered milk-sugar. This mixture is very successful in practice. The behavior of the mixture, when coagulated with dilute acid, is strikingly like that of human milk.

Changes Produced in Milk by Disease.—The milk of a strong, healthy woman is more nourishing than that of the weak, sickly woman. The character of the secretion of milk in the human subject, as well as in some of the lower animals, is greatly varied by the emotions, and milk secreted during periods of excessive mental excitement has frequently proven poisonous to the young. Certain drugs pass through the mother into the milk, as, for example, iodine, arsenic, antimony, lead, zinc, bismuth, and mercury. Opium and morphine, although they may not be detected in the milk, have frequently passed into the milk in sufficient quantities to narcotize the infant. In the cow the character of the food and the state of the health have an important bearing on the composition of the milk. In cases of the cattle-plague the milk has been found to contain blood.

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The milk in cases of tuberculosis, a common disease in cows, is capable of communicating this disease to calves, as well as to human subjects. Milk from tuberculous cows should never be used. The milk from foot-and-mouth disease is also injurious. Milk is often the carrier of the infection of contagious diseases, as measles, scarlet fever, diphtheria, small-pox, and typhoid fever.

Milk is a good cultivating medium for the growth of various bacteria, and several characteristic bacteria producing coloring matters occur in milk, one giving it a blue, another a purple-red, and another a yellow color. Milk is sometimes rendered poisonous by certain bacterial growths. These poisons are either ptomaines or toxalbumins produced by the growth of these bacteria.

The Adulterations of Milk.—The adulterations usually practised are the extraction of cream, or the addition of water, or both. Occasionally the addition of some foreign substance, as sodium carbonate, common salt, or sugar, is met with.

The detection of the adulterations of milk usually depends upon the determination of the specific gravity, the fat, total solids, and the ash. The quantity of these ingredients is not perfectly uniform, and hence certain limits of allowable variation have been determined upon from time to time. The standard adopted in many States in this country is a specific gravity not less than 1029 and total solids not less than 12 per cent., of which 3 per cent. shall be fats. The legal limits for total solids vary from 12 to 13 per cent., and the solids not fat from 8.5 to 9.5 per cent. The Society of Public Analysts of Great Britain have adopted for total solids, 11.5 ; fat, 3 ; and solids not fat, 8.5 per cent.

Milk Testing.—There is no instrument of simple construction which will with certainty detect the presence of a small amount of adulteration in milk. The **lactometer**, or **lactodensimeter**, which has been employed very largely in the sanitary inspection of milk, is a hydrometer with a scale covering the variations usually met with in milk. (See Fig. 67.) The **lactometer** of the New York Board of Health is a hydrometer on which the scale is so constructed that 100° indicate a specific gravity of 1029, the supposed lowest specific gravity of pure milk. The space between 1000, the specific gravity of water, and 1029 is divided into 100 arbitrary degrees. The scale is extended to 120°, which corresponds to a specific gravity of 1034. When taken alone, it is of very little value. If, however, it be taken with the estimation of either the total solids or the fat, it is of considerable service. In very exceptional cases the milk of a single cow may have a specific gravity below 1029, but such milk should be regarded as abnormal. Such depression of the

specific gravity never occurs in the mixed milk of several well-fed cows. A specific gravity below 1029, therefore, unless accompanied by an excessive amount of fat, may be taken as evidence of contamination, probably with water.

The fat for such examinations may be estimated by the creamometer, or by some form of lactoscope, or the lactobutyrometer. The cream-ometer, or cream gage, is simply a graduated cylinder, the graduations being $\frac{1}{100}$ of the total capacity of the cylinder to the zero mark. (See Fig. 67.) The milk is added in the cylinder to this zero mark, and allowed to remain at rest for twenty-four hours, when the number of the divisions covered by the cream is read off. This should not be
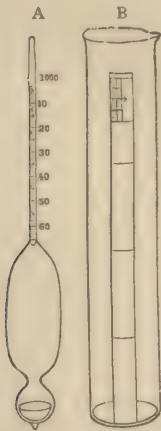
FIG. 67.—A. HYDROMETER. B. CREAM-OMETER.—(*Starr.*)
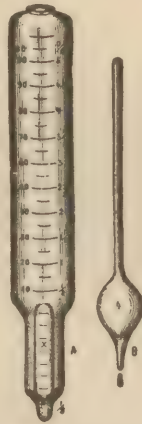
FIG. 68.—FESER'S LACTOSCOPE.—(*Queen.*)

less than ten per cent. The **lactoscope** depends upon the assumption that the opacity of the milk is proportional to the amount of fat which it contains. In **Feser's lactoscope** (Fig. 68), a measured volume of milk is placed in a graduated vessel, A, by means of the pipette, B. It is then diluted with water until the black lines of the inner cylinder of opaque white glass can be seen through the layer of the mixture between the walls of the inner and outer cylinders. It is then only necessary to read off the percentage of fat on the scale of the outer cylinder at the surface of the liquid. This method of determining the fat in milk, although answering for the purpose of municipal control, is not to be depended upon for scientific purposes, or as

evidence upon which to base legal proceedings.   The lactoscope is
of doubtful value in estimating the fat in human milk.   In a large
experience with this instrument the author has seldom seen the
readings vary more than 0.3 per cent., in cows' milk, from the
accurate methods.   Usually it is much nearer than this.

The **Chemical Analysis of Milk.**—An easy, rapid, and satis-
factory method for estimating the fat in milk is that known as the
Werner-Schmid process.   Ten c.c. of the milk are measured
out into a long test-tube, holding 50 c.c. and graduated at every 10
c.c., and treated with 10 c.c. of strong HCl.   If desired, the milk
may be weighed into a small beaker-glass and then washed into the
test-tube with the acid, when the test-tube need
not be graduated.   After mixing the milk and
acid together, the mixture is heated to boiling,
or, it is loosely corked and heated in a water-bath
for five or ten minutes, or until the liquid turns
brown, but not black.   The tube and contents
are then cooled, 10 c.c. of well-washed ether
added, corked, and the mixture well shaken.   As
soon as the ether separates from the remainder of
the fluid, the cork is removed and the wash-bottle
arrangement shown in figure 69 inserted.   The
lower end of the exit tube is now adjusted by
sliding it in the cork so that it is just above
the line of separation of the two fluids.   The
ether solution of the fat is now blown off into
a weighed beaker or flask.   Two more portions
of ether, of 10 c.c. each, are added, shaken up,
and blown off into the first portion.   The ether
is now distilled off and the fat dried in a
water-oven and weighed.   The amount of fat
so obtained represents that contained in 10 c.c.
of milk, or in the amount weighed out.
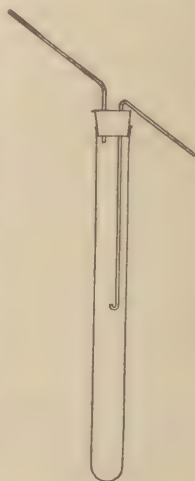
FIG. 69.

The results agree quite closely with the **Adams method**, described
below.

The **total solids and water** are determined by placing in a
weighed platinum dish a weighed quantity of the milk to be tested—
say, about 5 gm.   This is then placed upon a water-bath and evap-
orated to dryness.   It is now transferred to the water- or air-oven,
and dried at 100° C. until it ceases to lose weight.   The loss in
weight represents the water ; the residue represents the total solids.
Where great accuracy is unnecessary, the fat may be determined in
the residue by treating it with warm ether and pouring this through a

small filter, and repeating this process until the fat is completely dissolved out, which will require usually about 75 c.c. of ether. The ether is allowed to evaporate, and the fat which remains behind is weighed ; or, the residue left in the dish may be again weighed, when the difference between this weight and the weight of the dry solids will give the amount of fat. The results are about 0.3 per cent. too low.

The ash may now be determined by igniting, at a dull-red heat, the residue left after treatment with ether until all the organic matter is burned off, weighing the residue, and calculating it as ash.

The Centrifugal Method.—This method of separating the fat from milk for analytical purposes is quite satisfactory. The centrifugal machine has, in recent years, come into common use both in the chemical laboratory and in the physician's office.

In Babcock's method the milk is mixed with an equal volume of commercial sulphuric acid in a specially constructed bottle, provided with a long, narrow, graduated neck. After whirling the bottle in a centrifugal machine, the fat is separated, and the percentage is read off on the scale on the neck of the bottle. Leffman and Beam * have modified the process by adding to the milk a small quantity of a mixture of amyl-alcohol and hydrochloric acid, before adding the sulphuric acid. The size of bottle, the quantity of milk taken, and the centrifugal machine used is somewhat different from those of Babcock. More recently, this method has been modified by Koplik so as to adapt it to the small centrifugal machines used by physicians (Fig. 75). This is especially valuable in the examination of human milk. It requires little skill, is quickly done, and the results are quite satisfactory.

The necessary pipettes and bottles are shown in figure 70.

The process of making a determination of fat by this method is as follows : Fill the pipette to the mark with the milk to be examined. This represents 2.92 c.c. of milk. Introduce the end of the pipette carefully, so that the end is well into the body of the bottle, before delivering the milk. Cleanse the pipette, fill it with pure, strong sulphuric acid, and pour this into the milk in the bottle, with the same care as before. Add 0.6 c.c. of a mixture of equal parts of amyl-alcohol and pure concentrated hydrochloric acid. Mix the contents of the bottle by a rotary motion, and then fill the bottle with a freshly prepared mixture of equal parts of sulphuric acid and water. Two bottles are thus prepared and placed in the machine and rotated two or three minutes, when the fat will have separated and the percentage may be

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* "Analysis of Milk," P. Blakiston's Son & Co., Philadelphia.

read off on the graduated neck of the bottle. The space between the
smaller lines represents 0.3 per cent. of fat. To insure greater
accuracy, it is best to use a small hand magnifying glass, with the aid
of which ½ or even ¼ of a division may be read, and thus indicate
0.1 per cent. If the fat layer is seen to cover 8 divisions on the
scale, the percentage of fat in the milk is 2.4. If it covers 10 divi
sions, it indicates 3 per cent. of fat. The amyl-alcohol and hydro-
chloric acid mixture may be kept for some weeks, but when it has
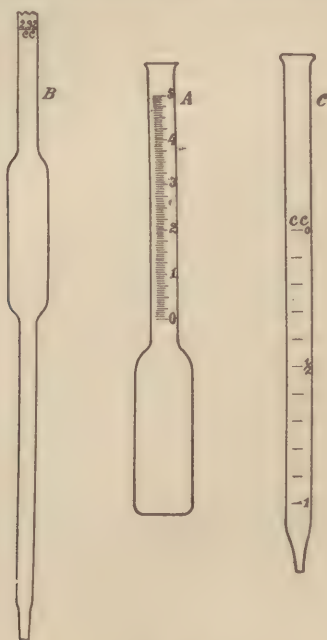
FIG. 70.

become dark-colored it must be renewed. These tubes are made by
Richards & Co., New York.

For this estimation there is needed a specially graduated bottle (A,
Fig. 70), a pipette (B), delivering 2.92 c.c., for measuring the milk
and the sulphuric acid, and a 1-c.c. pipette (C), graduated into tenths,
for measuring the mixture of amyl-alcohol and hydrochloric acid.
Special aluminum receivers for the bottle (A) are adapted to the
ordinary centrifuge, such as shown in figure 75.

Calculation of Fat from Total Solids and Gravity.—This method is useful when great accuracy is not demanded, and may be used in clinical examinations of human milk. It rests upon the assumption that one per cent. of milk solids not fat raises the specific gravity by a definite amount, while one per cent. of fat lowers it by a definite amount. An accurate determination of the specific gravity and total solids will, therefore, furnish the necessary data for calculating the amount of fat. The formula by which the calculations are made is that of Hehner and Richmond. It is as follows: $F = 0.859 \, T - 0.2186 \, G$, in which $F = $ fat, $T = $ total solids, and $G = $ specific gravity, as expressed in the third and fourth figures. Or, when the fat is known, the formula may be transposed so as to calculate the total solids, as follows:

$$T = \frac{F + 0.2186 \, G}{0.859}$$

The specific gravity must be determined with care, and for rapidity only 5 c.c. of milk are evaporated to dryness to determine the total solids. This may be conducted in a watch-glass, using 2 or 3 c.c., if a platinum dish is not at hand.

To illustrate the use of these formulæ let us assume, in the examination of a given milk, that the specific gravity, or G, was found to be 1030, and that the total solids, on examination, gave 12 per cent. Substituting these figures in the above formula, we have:

$$\text{Fat} = 0.859 \times 12 - 0.2186 \times 30 = 3.75.$$

Or, if the fat has been determined instead of total solids, and found to be 3.75 per cent., then:

$$\text{Total solids} = \frac{3.75 + 0.2186 \times 30}{0.859} = 12.$$

Another method has been proposed for calculating the solids not fat, from data afforded by the lactometer, specific gravity and Feser's lactoscope, by means of the formula $\dfrac{G - A}{0.00375}$, where G equals the specific gravity of the milk and A the remainder obtained on multiplying the percentage of fat, as shown by the lactoscope, by 0.001 and deducting this from 1000. For example: Suppose in a given sample of milk the specific gravity, or G, is found to be 1030. The value of A in the above equation will be found by multiplying the per cent. of fat, 3.7, by 0.001, which will be equal to 0.0037, which, deducted from 1000, equals 0.997. Substituting 1030 for G, and this remainder, 0.997, for A in above equation, we have:

$$\frac{1030 - 0.997}{0.0037} = 8.9 \text{ per cent. of solids not fat.}$$

These short methods will be found useful in the examination of human milk, where long, tedious processes are not likely to be entered into.   While some of them are not scientifically accurate, they are sufficiently so for clinical purposes and for the use of sanitary inspectors in sorting milks.

In the accurate estimation of the fat in milk, the officially recognized method is that of Adams.   Instead of drying the solids in the usual way, the milk is absorbed by bibulous paper previously thoroughly exhausted with ether and alcohol.   This paper is usually cut in the shape of long strips, and these are rolled into a coil and put in a special apparatus known as an extractor, and shown in figure 71.   The coil is put into the chamber of the middle piece of the apparatus, which is then connected with a condenser, as shown.   Sufficient ether to fill this chamber is put into the flask below, which is gently warmed.   The ether distils up into the condenser and runs back upon the coil, filling the chamber until it flows over through the siphon-tube into the flask below.   This is repeated until exhaustion is complete.   The ether is finally distilled off, and the fat in the flask is dried and weighed.   The results obtained by this method are about 0.3 per cent. higher than those obtained by the method above described, of evaporating in a platinum dish and treating with ether.   This has been adopted by official chemists, both in England and in this country, as the standard method of estimating fat.   For the accurate estimation of fat in milk in well-equipped laboratories, it leaves little to be desired in the way of accuracy, but is difficult without these facilities.
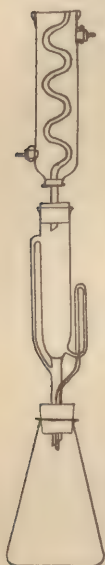
FIG. 71.

Milk Standards.—For ordinary purposes the estimation of the total solids, the fat, and the ash are considered sufficient to determine the question of the adulterations usually met with in the market.   The standards that have been fixed by law in a number of the States all refer to specific gravity, fat, and total solids.   Prosecutions are, therefore, usually based on these data.   To calculate the percentage of pure milk in a mixture, the following formula may be adopted, based upon the legal standard of the State of New York—viz., 12 per cent. of milk solids, 3 per cent. of fat, and 9 per cent. of solids not fat:

$$9 : \text{solids not fat} :: 100 : x = \text{milk used in making 100 parts of the mixture.}$$

For other standards the first member of the equation will be the

legal percentage of solids not fat. When the solids not fat are less than 9 per cent., it indicates some form of falsification. Suppose, for example, the solids not fat in any given analysis were 8.1. Substituting this in the above proportion, we have :

$$9 : 8.1 : : 100 : x = 90;$$

or, this sample of milk had been made from 90 per cent. of milk and 10 per cent. of water. If the milk is skimmed, the percentage of fat removed can be ascertained by the following formula :

$$\tfrac{2}{9} \times S - F = x;$$

in which S = solids not fat, and F = fat found. Suppose, for example, the fat in a given case be 2 per cent. and the solids not fat 8 per cent. Substituting these in the above equation, we have :

$$\tfrac{2}{9} \times 8 - 2 = x = 2;$$

that is, 2 per cent. of fat has been removed from this milk.

The Estimation of Sugar.—For clinical purposes a sufficiently correct estimation of milk-sugar can be made by exhausting the residue that remains after the extraction of the fat from the dry solids with ether with weak boiling alcohol. This dissolves the sugar and the soluble portion of the ash. The solution is filtered, evaporated to dryness in a platinum or a porcelain capsule, and weighed. The residue is then ignited and the ash weighed and deducted from the weight of sugar and ash, to obtain the amount of sugar.

Lactose may also be estimated with Fehling's solution, after coagulation with acetic acid and removal of the casein.

The Determination of Casein.—Casein and albumin are generally determined by difference. When the direct determination is desired, they may be precipitated by tannin, filtered, the precipitate dried, and washed with a mixture of one part of alcohol to three of ether until the washings show no trace of tannin. The residue is then dried and weighed.

The albuminoids can also be determined by the method of Ritthausen, who employs a solution of $CuSO_4$, containing 6.5 gm. to the liter, and a solution of alkali of the strength of 14.2 gm. of KOH or 10.2 gm. of NaOH to the liter. The copper salt precipitates the albuminoids, together with the fat. Twenty c.c. of milk are taken, and diluted with water to 400 c.c. ; 10 c.c. of the copper solution are then added, with constant stirring, until the coagulum settles and the supernatant liquid is clear. The alkali solution is now added until the liquid is neutral, and the contents of the beaker are filtered, using a

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previously dried and weighed filter-paper. The precipitate is all trans-
ferred to the filter. It is washed first with water, then with diluted
alcohol, and finally with ether, until all fat is removed. The remaining
precipitate is again washed with alcohol and dried at 110° C. (230° F.)
and weighed. The bluish mass is burned, and the loss, after deduct-
ing the weight of the filter-paper, is reckoned as casein and albumin.

Estimation of Caseinogen and Albumin.—In the examina-
tion of human milk, it is a matter of great importance to know the
proportion between the albumin and caseinogen, because of the great
importance of this ratio in infant nutrition. A rapid and easy method
of separating these proteids for analytical purposes is very desirable,
and several processes have been proposed. The most of them require
too much time for clinical purposes. Berggran and Winkler have
proposed a volumetric method based upon the fact that the proteids
of milk form insoluble compounds with a solution of potassium-
mercuric iodide containing ferric chloride, containing a fixed and
known amount of free iodine.

The solutions used are :

1. A solution of 0.2 gm. of mercuric iodide dissolved in 10 c.c.
of a 10 per cent. solution of potassium iodide. To this is added
1 c.c. of a 10 per cent. solution of ferric chloride, and the whole
made up to 100 c.c. with water. This solution should be made fresh
each twenty-four hours, as it does not keep well. The potassium-
mercuric iodide and ferric chloride may be kept in two separate
solutions, which may be mixed when required.

2. A $\frac{1}{100}$ normal solution of sodium thiosulphate, made by dissolv-
ing 2.476 gm. of selected crystals in a liter of water. Each c.c. of this
solution should exactly decolorize 1 c.c. of solution No. 1 in the
presence of a few drops of starch solution.

3. A solution of starch made by boiling 1 gm. of starch in 100 c.c.
of water and filtering. The milk to be examined is allowed to stand
until the cream has separated, or the most of the cream is separated
with the centrifugal machine.

Five c.c. of the skimmed milk are diluted with 20 c.c. of water,
and to this exactly 5 c.c. of solution No. 1 are added. After
standing five minutes, a few drops of solution No. 3 are added, and
the solution titrated with solution No. 2 until the blue color is
discharged. If the relation between solutions Nos. 1 and 2 is known,
it is easy to determine how many cubic centimeters of solution
No. 1 have been used by the proteids.

Suppose, for example, 5 c.c. of skimmed milk be treated with 5 c.c.
of solution No. 1, and the titration with solution No. 2 required
0.4 c.c.

Suppose a previous titration of 5 c.c. of solution No. 1 required 5.3 c.c. of solution No. 2. One c.c. of No. 2 then corresponds to 5 ÷ 5.3 = 0.943 c.c. of solution No. 1, and to 0.000943 gm. iodine. The back titration in the above example required 0.4 c.c. of solution No. 2, and therefore there was the difference between 5.3 and 0.4 c.c. used by the proteid in the 5 c.c. of milk, or 4.9 c.c.

4.9 $\times$ 0.000943 = 0.00462 = 0.00462 gm. iodine, combined with the proteids.

By a large number of analyses, it has been found that 1 gm. of iodine is precipitated by 16 gm. of milk-proteids, and therefore by multiplying the iodine used by 320, the proteids in 100 c.c. of milk are found. In the above example:

0.0046 $\times$ 320 = 1.472 gm. proteid in 100 c.c. of milk.

To estimate the albumin, 10 c.c. of milk are put into a 50 c.c. flask or cylinder, diluted, warmed on a water-bath to 40° C., and a few drops of acetic acid added and made up to the mark. The liquid is filtered, 25 c.c. of filtrate taken (5 c.c. of milk), and treated exactly as above. The difference between the total proteids and the albumin obtained by the second titration will represent the caseinogen.

Detection of Impure Water.—The addition of water to milk, if it be pure water, can be regarded as harmless to adults. It is rather a sophistication than a harmful adulteration. As this is usually well-water, which may itself be impure, it becomes a matter of importance, because the water may carry with it germs of typhoid fever, cholera, or other diseases, and will impart to the milk infectious properties. To detect impure water in milk the following process may be used: The milk is coagulated with acetic acid and filtered. To a suitable quantity of the whey add equal parts of a solution of naphthylamin sulphate and a freshly prepared solution of sulphanylic acid in sulphuric acid. The test may be made in an ordinary test-tube or in a cylinder. If the milk contains nitrites, due to an impure water, a rose-red color will appear, varying in intensity with the amount of nitrites present, and deepening on standing. The test is very delicate (p. 147). The following may also be employed: 100 c.c. of the milk are boiled with 1.5 c.c. of a 5 per cent. solution of $CaCl_2$, and filtered. A small portion of the filtrate is treated with H_2SO_4 containing 2 per cent. diphenylamin. This mixture is then floated upon concentrated H_2SO_4, when, if nitrates or nitrites be present in the milk, a blue zone will appear at the line of contract of the two liquids. Or, the test may be applied as follows: 1 c.c. of a solution of diphenylamin in H_2SO_4, is placed in a small porcelain dish, and a few drops of the milk allowed

to flow down the side into the acid. If the milk contains nitrites or nitrates, a blue color will appear at the line of separation between the acid and the milk. This test is very delicate, and will detect the presence of a very small quantity of impure water. Nitrites and nitrates are not found in milk, even if contained in the food of the cows.

Determination of the Duration of Lactation.—For this purpose Umikoff suggests the color produced by ammonia in human milk. To 5 c.c. of the human milk to be tested, add 2.5 c.c. of a 10 per cent. ammonium hydroxide solution, and warm the mixture to 60° C. for fifteen to twenty minutes. Human milk when so treated assumes a reddish-violet color, the intensity of which increases with the duration of lactation, from rose-violet to dark-brown violet.

Condensed Milk.—Owing to the difficulty of keeping ordinary milk, several processes of preserving it by concentration have been employed. As early as 1837 Newton preserved milk by evaporating it in shallow pans at 50° C. (122° F.), during which time air was blown through the milk. From that time to the present, preserved or condensed milk has been an important article of commerce. When milk is simply evaporated, without the addition of a preservative, it is called **condensed milk.** This is also put into the market sometimes under the name of evaporated cream. This term is also applied to what properly should be termed **preserved milk, or** milk which has been condensed, with the addition of cane-sugar. Preserved milk is much thicker in appearance than condensed. Milk is usually condensed to about one-third its original volume, although the makers usually claim that it is condensed to one-fourth its original volume. Analyses of a large number of samples made at various times in this country give the average as a little short of one-third. The addition of 2 parts of water to 1 of condensed milk should, therefore, produce a milk of the same degree of richness as the whole milk before condensation. Analyses made by Cornwall, of the condensed milks found in the American market, showed the following average :

Water, ... 26.95 per cent.	Milk-sugar, ... 13.38 per cent.
Milk solids, ... 34.36 "	Cane-sugar, ... 38.82 "
Casein and albumin, . 9.25 "	Ash, ... 1.92 "
Fat, ... 9.69 "	

Calculating from these results, he found that the condensation varied from 2.27 to 3.12 times, the average of all analyses being about 2.74 times, or the milk was condensed to not quite one-third the original volume. Condensed milk is largely used as a nourishment for young infants. For this purpose it is usually diluted with

about 9 to 12 parts of water. Meigs has shown that if 1 part of the best commercial sweetened condensed milk be mixed with 9 parts of water, the mixture somewhat closely resembles in composition that of human milk, with the exception that it is deficient in fat, and that this mixture, with a small portion of cream added, gives a milk of nearly the chemical composition of human milk. In digestibility, condensed milk is inferior to cows' milk or human milk. It is open to the objections above mentioned to sterilized milk. It is open to the additional objection that a large part of the sugar present, when sweetened milk is used, is cane-sugar instead of lactose, the natural sugar of milk. Cane-sugar more readily undergoes acid fermentation in the stomach or intestine of the infant than lactose. Infants fed exclusively upon condensed milk show a tendency to develop rickets, or, a failure of the nourishment of the bony structures. As a result, the development of the teeth, and the ability to walk are somewhat delayed.

THE URINE.

The urine is an excretory fluid thrown off by animals. It is partially filtered from the blood by the kidneys, and partly elaborated by these organs from waste materials found in the blood. It is composed of a watery solution of certain inorganic salts and nitrogenous principles which are of no further use to the body. As will be seen from the table at the end of this chapter, human urine is not a liquid of uniform composition, but subject to very considerable variations. These variations may be physiological, or they may be indicative of diseased conditions, and a knowledge of them is essential to a correct diagnosis of many diseases.

General Physical Properties.—Normal urine, when fresh, is a clear, amber-colored, transparent liquid, having a peculiar, aromatic, characteristic odor, a bitter, saline taste, a distinctly acid reaction, and a specific gravity of from 1018 to 1022. The average specific gravity is generally given as 1018 to 1020. When it is kept in a clean vessel and away from contact with air, it will undergo but slight changes in several days.

Composition.—The urine is chiefly a solution of urea and certain organic and inorganic salts, holding in suspension epithelial cells and mucus. The composition will be found in the table at the end of this chapter, with the chief variations met with in diseased conditions, and their significance. The urine, like milk and other animal

fluids, is not of constant composition. It is influenced by the amount of water and other fluids taken ; by the temperature of the skin ; by the emotions ; by the blood-pressure, local or general ; by the amount of work done, the time of day, the age, the sex, the influence of medicine, etc.

Quantity.—The **quantity** of urine passed in twenty-four hours varies considerably. The average daily quantity passed by a healthy adult is from 1400 to 1600 c.c., or about 50 fluidounces. The quantity of total solids contained in this is about 60 gm., or 1000 grs., and about one-half of these solids is composed of urea.

The variations in the quantity will be found in the table at the close of this chapter.

The Color and Transparency.—In health, the color is usually a light amber. In general, the greater the quantity, the lighter the color; and the smaller the quantity, the darker the color. As the color deepens by concentration, it becomes more reddish. The color, as well as the quantity, is subject to great variations, even in health. It may vary from almost as clear as water to a dark yellowish-red, according to the degree of concentration. After drinking large quantities of fluids, the quantity is very much increased and the color is light. After severe sweating, or in abstinence from drinking, it becomes concentrated and darker in color. The normal color of the urine is due to several more or less closely allied pigments, the chief of which are **urobilin** and **uroxanthin.** (See p. 526.) These coloring matters are probably derived from the biliary coloring matters. The abnormal coloring matters are chiefly those of the blood or bile, melanin, hemoglobin, and coloring matters due to medicinal substances, and certain vegetables. An excess of the normal pigments of the urine may be expected in febrile conditions, and in diseases in which the blood-cells are undergoing rapid destruction. Urobilin, when it exists in excessive quantities, colors the urine a dark brownish-red, even without concentration, and the foam of such a urine is of a yellow or yellowish-brown color. There is a marked increase of urobilin in conditions where the hepatic cells fail to perform their proper function ; that is, in the condition known as biliousness. In such cases the skin and other tissues may also show the presence of the same yellow color.

The Tests for Urobilin.—First. The spectroscopic examination shows absorption bands in the green, between the lines b and F. In order to see these lines, it is often best to dilute the urine by pouring water carefully upon the top of the heavier urine in the testtube. After allowing the liquids to remain at rest for a short time, examine the water above the urine for the absorption bands.

Second. Chemically, we may test for urobilin by the addition of ammonia to the urine, when, if much urobilin be present, it gradually assumes a greenish hue. It is then filtered and a watery solution of $ZnCl_2$ added, when there appears a rose-red color with greenish fluorescence, due to urobilin.

Uroerythrin and **urochrome** have been described as occurring in urine, but little is known of them.

The coloring matters of the bile and the blood will be considered again.

Certain medicines and vegetables, when taken by the mouth, may color the urine. Rhubarb and senna give the urine a brownish color ; if made alkaline, it becomes a purple-red. The coloring agent in this case is the chrysophanic acid found in these medicines. After taking logwood, the urine becomes reddish, or violet when made alkaline. Santonin colors it yellow or greenish-yellow, which, on the addition of an alkali, changes to red. Picric acid also gives a yellow color, which does not change to red on the addition of an alkali. Phenol, naphthalin, creosote, preparations of tar, or arsin (AsH_3), impart either a greenish or a greenish-black color to the urine. Salol, resorcinol, antipyrin, and several other coal-tar remedies some-times cause the urine to assume a violet-red or brown color. Brown or brownish-black urine is observed in patients with melanotic tumors. The coloring matter in this case is melanin.

Transparency.—Normal urine is transparent, containing only a slight flocculent cloud of mucus, visible after standing a few minutes. If the urine is turbid when passed, it is pathological. It is usually turbid in all diseases of the urinary passages, from the excessive amount of mucous and epithelial elements, and because the urine in this condition readily undergoes alkaline fermentation in the bladder, when the earthy phosphates are precipitated as a white sediment. In fevers, the quantity of urine is occasionally so small that the urates separate even in the bladder, and especially is this the case in certain diseases of children, where oxidation is deficient, as in capillary bronchitis and pneumonia. Admixtures of blood, pus, and chyle make the urine turbid. The most striking turbidity is produced by the admixture of chyle, which gives it a milky-white appearance. Here the milky appearance is due to an admixture with the urine of emulsified fat and imperfectly dissolved proteids. Many urines which are clear when passed become turbid on standing, from the separa-tion of the acid urate of sodium or ammonium. The turbidity of alkaline urine has already been mentioned. All urines become turbid on standing for a few days, from the appearance of swarms of bacteria in the solution. Such turbidity can not be separated by

filtration through paper. They can be removed by shaking the urine with some insoluble powder and repeated filtration. Powdered glass, silica, or talcum answers the purpose.

Specific Gravity.—This varies from 1015 to 1028, according to the degree of dilution or concentration. Pathological urines may vary from almost that of water to 1050. As a rule, the urine of Bright's disease is of low specific gravity, while in diabetes mellitus, and in all acute fevers, it is of high specific gravity. The specific gravity of urine is generally determined by the urinometer, which is a small hydrometer graduated to include the variations in specific gravity usually found in urine. (See p. 21.) It is usually graduated so that only the last two figures of the specific gravity appear upon the stem, and so as to read correctly at 60° F. If the temperature is above 60° F., it will be sufficiently accurate for clinical purposes to add one degree in specific gravity for every 3° C. (5.4° F.) in temperature—*i. e.*, if it read 1018 at 80° F., it would read 1024 at 60° F. The ordinary urinometers of the market are apt to be unreliable. It is best, therefore, to test the instrument by careful determinations of the specific gravity of solutions of common salt, with the specific gravity flask, and compare the readings of the urinometer with these determinations.

The urinometer is used as follows : The urine is placed in the upright jar, or cylinder, wide enough and deep enough to allow the instrument to float freely. When it has come to rest, the surface of the fluid in the jar is brought to the level of the eye, and the reading taken at the lower edge of the meniscus formed by the upper surface of the urine. The mark on the instrument which is cut by this line, and which can be distinctly seen, is taken as the correct reading. If the urine be turbid, this method can not be employed, as the reading will be more or less uncertain. Should the quantity of urine at hand be not enough to float the urinometer, it may be diluted with an equal volume of water, the specific gravity taken, and the last two figures multiplied by two, to get the true specific gravity.

Reaction.—Normal urine is faintly acid, and grows more acid for a few hours after being voided, due to the so-called "**acid fermentation.**" During this period of acid fermentation there is frequently deposited a whitish or pinkish, or, at times, reddish sediment, due to the separation of the acid urate of sodium or to crystals of uric acid. This sediment disappears again on warming the solution. On standing still longer exposed to the air, the acidity grows less and less, and at the same time an odor of ammonia begins to be developed, and finally the reaction changes from acid to neutral, and from neutral to alkaline, with a strong odor of ammonia and more or less odor of

putridity. The rapidity with which these changes take place is dependent upon the composition of the secretion, and upon the temperature, taking place more rapidly in warm than in cold temperatures. An abundance of mucus, which can usually be seen after a few hours as a light, flocculent cloud, settling near the bottom of the vessel containing the fluid, greatly hastens these fermentative changes. This is especially the case if the bladder or the kidneys are in a diseased condition. There is produced with the mucus, especially in diseased conditions of the bladder, a peculiar soluble ferment, which hastens the decomposition of urea and the production of ammonium carbonate.

The reaction of urine is best tested by dropping a small piece of a red and a blue litmus paper into the solution. If both are found red after a few minutes, the reaction is acid. If both are blue, it is alkaline. If they remain unchanged, the reaction is said to be "amphoteric." If the alkalinity be due to ammonium carbonate, the red paper, on drying and warming over a flame, turns red again. If due to the fixed alkalies, it remains blue on drying and warming.

The fermentation of urine is due to certain micro-organisms, of which the **micrococcus ureæ** is the best known. Normal urine is free from these organisms when passed, but in certain abnormal conditions it may undergo an alkaline fermentation while still in the bladder, and that apparently without the intervention of these organisms. It has been found that the fermentation may be complete in the presence of an amount of carbolic acid which is fatal to the development of micro-organisms. It has been assumed that an enzyme is secreted with the thick, mucous secretion of vesical catarrh, which possesses active hydrolytic powers on a solution of urea. As the urine becomes alkaline, from the production of ammonium carbonate from urea, it becomes turbid and acquires a paler color. $CO(NH)_2 + 2H_2O = (NH_4)_2CO_3$. The phosphate of calcium and the ammonium-magnesium phosphate, which separate when the urine becomes alkaline, and to which the turbidity is due, are generally called the **earthy phosphates.** The latter of the two is called the triple phosphate, and is found in nearly all alkaline urines.

Estimation of Acidity.—The acidity of the urine diminishes slightly after a full meal. It follows very nearly the acidity of the stomach contents. It is increased by gastric fermentation and in hyperchlorhydria.

The acidity of the urine increases with the amount of uric acid excreted. The total acidity of normal urine is equivalent to the acidity of 2 to 4 gm. of oxalic acid in twenty-four hours. The greater part of this acidity is due to the acid sodium

phosphate produced by the reaction of uric acid upon Na_3PO_4, and the rest is due to the organic acids, most likely lactic.

$$Na_3PO_4 + 2C_5H_2N_4O_3H_2 = 2NaHC_5H_2N_4O_3 + NaH_2PO_4.$$
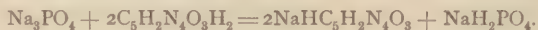
The acidity may be estimated by a decinormal solution of sodium hydroxide : 25 c.c. of the urine are diluted with 75 c.c. of water in a beaker ; 3 drops of an alcoholic solution of phenolphthalein are added, and a decinormal alkali run in from a burette, until a slight pink color is produced. The urine must be fresh for this estimation. Instead of phenolphthalein we may use blue litmus paper as an indicator, taking out a drop of the solution on a glass rod from time to time, and touching the paper. A violet tint indicates neutrality. The acidity may be calculated as phosphoric acid, as acid sodium phosphate, or, as is frequently done, as oxalic acid. Each c.c. of the decinormal alkali is equivalent to 0.0049 gm. of phosphoric acid, or 0.012 gm. (0.01198 more exactly) of acid sodium phosphate, NaH_2-PO_4. or 0.0063 of oxalic acid ; 100 c.c. of urine should require from 20 to 40 c.c. of $\frac{N}{10}$ NaOH.

Total Solids.—As stated above, the normal amount of solids passed by an adult in twenty-four hours is about 60 gm., or 1000 grs. An approximate estimation of the total solids may be made by multiplying the last two figures of the specific gravity, carefully taken, by the factor 2.33, which will give the number of gms. of solid matter in 1000 c.c. of urine, from which it will be easy to calculate the amount in twenty-four hours. If, for example, the quantity in twenty-four hours be 1500 c.c., and the specific gravity 1020, the total solids would be $20 \times 2.33 = 46.6$ gm. of solids in 1000 c.c. In 1500 c.c. there will be 1.5 times as much, or 69.9 gm. If it be desired to use English measures, we may determine the total solids by multiplying the last two figures of the specific gravity by the number of fluidounces passed. This calculation is based upon the result of numerous exact determinations, which show that the last two figures of the specific gravity very nearly represent the number of grains of solid matter in one fluidounce of urine. Thus, if the number of fluidounces be 50, and the specific gravity 1020, then the total solids will be $50 \times 20 = 1000$ grs. These methods of calculating the total solids give only approximate results, but in most cases will be found sufficiently accurate for clinical purposes.

A more exact method for determining the total solids is to evaporate 10 c.c. in a porcelain dish or watch-glass, and dry in a water-oven to constant weight. The difference between the weight of the dish and of the dish with the solids, will give the weight of the solids in 10 c.c. of urine. Even by this method there is some loss during evaporation.

Odor.—The odor of normal urine has been described as aromatic. A putrid odor is due to the products of decomposition.   Occasionally the urine is putrid when passed, the putridity being due to the decomposition of pus, albumin, or some other foreign matter mixed with the urine in the bladder.   Sulphuretted hydrogen sometimes occurs in the urine, and a fecal odor is occasionally met with, indicating a fistulous opening between the bladder and the intestine, or an abscess between the bladder and rectum.   A number of substances, when taken internally, cause the urine to assume a characteristic odor.   Many aromatic substances impart their odor, as oil of turpentine (giving the odor of violets), cubebs, copaiba, asparagus, garlic, valerian, etc.

INORGANIC CONSTITUENTS OF THE URINE.

The urine contains certain inorganic salts, especially the chlorides of potassium and sodium, the phosphates of potassium, sodium, magnesium, and calcium, and the sulphates of some of these metals, and several aromatic sulphuric ethers.   These salts are generally tested for by the detection of the corresponding acids.

The Chlorides.—For the detection of the chlorides, add a few drops of nitric acid, and then a solution of silver nitrate (1 : 20). The chloride of silver separates as a white, curdy precipitate, which should occupy not more than one-fourth the volume of the urine taken.   If the settled precipitate occupies much more or less than one-fourth the volume of the quantity of urine taken, the quantity is increased or diminished.   It is always best, in making this test, to compare the specimen under examination with normal urine.   In most cases this approximate estimation of the chlorides will be all that the clinician will demand.   Occasionally, however, it becomes necessary to make a more accurate determination.   For this purpose it is necessary to have a decinormal solution of silver nitrate—*i. e.*, a solution containing 16.96 gm. of pure silver nitrate, dissolved in a liter of distilled water.

Quantitative Estimation of Chlorides.—Dilute 10 c.c. of the urine with about 50 c.c. of water, and add a few drops of a rather strong solution of potassium chromate.   Now drop the silver solution from a graduated burette (see Fig. 64) drop by drop, until a permanent reddish color indicates that the chlorine has all been precipitated, and that the silver has begun to form silver chromate.   Ten c.c. of urine usually requires 15 to 20 c.c. $AgNO_3$ solution.   One c.c. of silver solution represents 0.00354 gm. of chlorine, or 0.00584 gm. of NaCl.   In highly colored urines this method is sometimes inapplicable, owing to the change of color being masked by the color of the urine.   In such cases it is best to use the following method :

Second Method.—When to a solution of silver nitrate, acidulated with nitric

acid, sulphocyanate of ammonium or potassium is added, a white precipitate forms, which is insoluble in nitric acid. If the fluid contains a ferric salt, a blood-red color forms at the moment when the last of the silver is precipitated. **Volhard's** method of estimating the chlorides makes use of this principle. The following solutions are needed in the process: (1) Pure nitric acid. (2) A strong solution of ferric alum (sulphate of iron and ammonia) free from chlorine. (3) A decinormal nitrate of silver solution, made by dissolving 16.96 gm. in a liter of distilled water. (4) A decinormal solution of potassium sulphocyanate, or of ammonium sulphocyanate; this should be of exactly the same strength as the silver solution; it is made by dissolving 6.5 or 7 gm. of the sulphocyanate in about 400 c.c. of water. To standardize the sulphocyanate solution, a portion of it is put into a burette, and 10 c.c. of the decinormal silver nitrate solution brought into a beaker with a few drops of the solution of iron alum. The mixture is well stirred and the sulphocyanate solution added, drop by drop, until a slight but permanent pink color appears. In accordance with the result obtained, the sulphocyanate solution is diluted to such a point that 10 c.c. of it will just neutralize 10 c.c. of the $AgNO_3$ solution. If, for example, 8 c.c. of the sulphocyanate produce a red color, we then know the amount of sulphocyanate in 8 c.c. is that which should be in 10 c.c. Therefore, we dilute the 8 c.c. with a sufficient amount of water to make it 10 c.c., or if we have 450 c.c. we shall add to every 8 c.c., 2 c.c. of water, or we make the calculation by the following proportion:

8 : 10 : : 450 : x = 562.5, or 450 c.c. of the solution first made up will require to be diluted to 562.5 c.c., or there must be added 125.5 c.c. of water. Having thus corrected this solution to make it agree in strength with that of the silver solution, we again compare them to see if it is correct.

The process is conducted as follows : 10 c.c. of the urine are measured out with a pipette and placed in a graduated flask of 100 c.c. capacity ; 50 c.c. of water are added, and then, successively, 4 c.c. of nitric acid and 25 c.c. of silver solution. The flask is closed with a glass stopper, and agitated until the precipitate ceases to form, and the fluid tends to clear. Distilled water is added, to the 100 c.c. mark. A portion of the fluid is then passed through a dry filter, and to 50 c.c. of this filtrate add a few drops of the iron-alum solution, and then the sulphocyanate solution from the burette until a red color appears. The amount of sulphocyanate solution added, deducted from the amount of silver solution added, gives the amount of silver solution used up by the chlorine in one-half of the 10 c.c. of urine, or 5 c.c.

The calculation is the same as in the first method.

The Phosphates.—Phosphoric acid exists in the urine about two-thirds combined with the alkaline metals and the remainder with lime and magnesium. These phosphates are, therefore, generally distinguished by the terms **alkaline** and **earthy phosphates.**

The **acidity** of the urine is generally believed to be due to the acid sodium phosphate, NaH_2PO_4. Sodium phosphate, Na_2HPO_4, is neutral in reaction, and Na_3PO_4 is alkaline.

In acid urines we have NaH_2PO_4, Na_2HPO_4, $CaHPO_4$, $CaH_4(PO_4)_2$, and $MgHPO_4$; while in alkaline urines we find in solution Na_3PO_4, and as precipitates $Ca_3(PO_4)_2$, $Mg_3(PO_4)_2$, and $MgNH_4PO_4$.

By adding an alkali to normal urine the phosphates of calcium and magnesium, termed earthy phosphates, are precipitated. When NH_4OH is added, all the magnesium present is precipitated as

NH_4MgPO_4. The phosphates of sodium and potassium remain in solution. The earthy phosphates may be approximately estimated by adding a few drops of ammonium hydroxide solution to the urine, and observing the amount of turbidity produced after boiling. This may be quickly done by the use of the centrifuge, in the graduated tube, and measuring the volume of the precipitate. By comparing this with the amount obtained by the same treatment of normal urine, it will indicate whether the quantity is excessive or deficient. The alkaline phosphates may be detected in the filtrate from the earthy phosphates by the addition of a few drops of $MgSO_4$ solution and some NH_4Cl. This precipitate should be about twice as voluminous as that produced by the earthy phosphates, and whether in excess, normal, or deficient, may best be determined by comparison with normal urine. The exact quantitative estimation of the phosphates is rarely required.

Sulphates.—Sulphuric acid occurs in the urine partly in combination with the metals, and partly in combination with certain aromatic bodies of putrefactive origin, called collectively the ethereal sulphates. The most important of these are phenol- and cresol-potassium sulphates, indoxyl- and skatoxyl-potassium sulphates, pyrocatechin- and hydrochinon-potassium sulphates. The two classes of sulphates are generally distinguished as the **preformed** or **mineral sulphates**, and the **conjugate** or **ethereal sulphates**. About nine-tenths of the total sulphuric acid are combined with the metals or are preformed. About one-tenth exists as ethereal sulphates of potassium. (See p. 471.) The preformed H_2SO_4 is detected by the addition of $BaCl_2$ in the presence of free HCl. It appears as a fine, white precipitate of $BaSO_4$, rendering the solution opaque, and milk-like in appearance. An approximate estimate may be made by comparing the turbidity with that of normal urine treated in the same way. An excess of sulphuric acid may be due to the taking of an excessive amount of sulphates with food or drink. It is the ethereal sulphates that have the chief clinical interest. They are derived from the putrefactions of proteids somewhere in the body. In the absence of any other source, an increased quantity of them present in the urine is usually taken as evidence of intestinal putrefaction. They are decomposed, on boiling with dilute mineral acids, into free sulphuric acid and the aromatic substance. The sulphuric acid which they contain is not precipitated in the cold by a slightly acidulated solution of barium chloride. An approximate estimation of the ethereal sulphuric acid may be made by precipitating the urine with an excess of barium chloride and a few drops of hydrochloric acid, filtering off the precipitated $BaSO_4$, and then adding to the filtrate one-tenth its volume

of pure HCl, bringing the solution to boiling, and then heating on a water-bath for one hour. The $BaSO_4$ obtained after this treatment of the filtrate represents the sulphuric acid existing as ethereal sulphates.

Potassium Indoxyl-sulphate, or Indican.—$C_8H_6N.SO_4K$. It is easier to test for the aromatic portion of the ethereal sulphates, and make an approximate estimation, than to estimate the sulphuric acid. This is especially true of indoxyl, the most important of them. It is found in normal urine in mere traces. It has a clinical import only when present in increased amount. It then has the same significance as the ethereal sulphates.

Indoxyl may be detected by the addition of an equal volume of strong hydrochloric acid, and dropping into this 2 or 3 drops of a solution of chlorinated soda. Immediately, or after a few seconds, there is formed just beneath the surface a bluish-black cloud of indigo. By stirring the chlorinated soda solution into the urine, we obtain, according to the quantity of indican present, a more or less dark coloration of the whole fluid. If we now shake the fluid with chloroform, the indigo is dissolved out by the chloroform and settles as a blue layer at the bottom. Care must be taken not to add too much of the chlorinated soda. We can judge of the amount of indoxyl by the depth of the blue color.

ORGANIC CONSTITUENTS.

Urea.—$CO(NH_2)_2$. Urea is the most important constituent of the urine, as it is the chief condition in which nitrogen leaves the body. It is by far the most abundant solid ingredient of the urine. Its chemical properties have already been described (p. 455).

Detection.—Urea may be detected by evaporating a few drops of urine on a glass slide, moistening the residue with nitric acid and allowing it to crystallize, and examining the crystals of urea nitrate, $CO(NH_2)_2HNO_3$, under a microscope of low power.

Estimation.—The estimation of urea in urine is a matter of considerable importance, as it is generally looked upon as an index of the nitrogenous metabolism going on in the body, or of the eliminating power of the kidneys. The quantity of urea excreted in twenty-four hours by a healthy adult of 150 pounds body-weight, and doing ordinary work, is usually stated to be from 30 to 33 gm., or from 430 to 550 grs. The quantity will be increased by an increased consumption of nitrogenous food or by hard work, and it will be diminished by a non-nitrogenous diet and by little exercise. In estimating what should be regarded as a normal amount of urea, · the condition of the patient, as to exercise, appetite, and dietary,

should be taken into account. Roughly, in the absence of sugar, albumin, and other abnormal ingredients, the urea may be regarded as one-half the total solids. The more accurate quantitative estimation requires so little time, apparatus, and skill that it is now very generally employed. The determination is based upon the fact that urea is decomposed by alkaline hypochlorites or hypobromites into carbon dioxide, water, and nitrogen.

$$CO(NH_2)_2 + 3NaBrO = 3NaBr + CO_2 + 2H_2O + N_2.$$
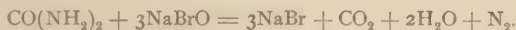
One c.c. of nitrogen at the ordinary temperature and pressure corresponds to about 0.0027 gm. of urea.

The liberated N escapes, and may be collected and measured, while the other products of the reaction remain in solution.

The hypobromite solution is prepared as follows: 100 gm. of NaOH are dissolved in 250 c.c. of water, and to this solution, when cold, 25 c.c. of bromine are added, and the solution kept cold. This solution contains sodium hypobromite, hydroxide, and bromate. The solution should be freshly prepared, as it readily undergoes decomposition. Owing to the instability of this solution and the excessively disagreeable handling of bromine, the author employs a solution of sodium hypochlorite, or chlorinated soda, with the addition of KBr. This solution acts as well, by the method to be described, as the above. Various forms of apparatus have been devised for the quantitative estimation of urea. The simplest of these is the one devised by Dr. C. A. Doremus, which is represented by figure 72. The tube, A, is filled with the above-mentioned solution of hypobromite, and 1 c.c. of urine is introduced with the pipette, B, as nearly as

FIG. 72.

possible at the center of the lower portion of the upright limb. The urea is decomposed and the N rises to the upper, closed end. After the decomposition is complete, the urea is determined by reading the graduations at the surface of the column of liquid. This ureometer, according to the graduation, gives either the milligrams of urea in 1 c.c. of urine, the percentage, or grains per fluidounce.
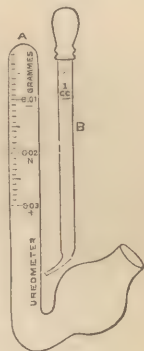
The author uses a graduated tube closed at one end. The graduations indicate at once the number of grains of urea in a fluidounce of urine, when 1 c.c. is taken for the estimation. (See Fig. 73.) The ordinary gas-tube may be used, when the readings will give the c.c. of nitrogen, from which the urea is calculated.

The process is conducted as follows: A 20 per cent. solution of

KBr is added to the fifth division of the ureometer. Chlorinated soda solution is then added to the fifteenth or twentieth division. The tube is now inclined and pure water poured carefully down the side of the tube and floated upon the top of the fluids already in it ; 1 c.c. of urine is then added, in the same inclined position, so that it will not mix with the reagents below, but remain in the water at the surface of the fluid. The tube is now firmly grasped in the right hand, with the thumb tightly pressed upon the open end. The tube is now inverted, and the contents well mixed. A rapid decomposition takes place, which is usually ended in from three to five minutes. During this time the liquid is kept agitated without violent shaking. As soon as the effervescence has ceased, the reading is taken at the surface of the fluid, with the tube still held in the inverted position. It is now opened under water, when the column of fluid in the tube will fall, and the reading is again taken. It is best to have a wide, deep jar for the water, so that the tube may be depressed to bring the surface of the liquid in the tube to the surface of the water in the jar ; but an ordinary bowl may be used, as the error caused by the difference in level of three or four inches of water is very slight. The difference in the two readings gives the number of grains of urea in a fluidounce of urine. This quantity, multiplied by the number of fluid-ounces passed in twenty-four hours, gives the amount of urea excreted in twenty-four hours, which should be not far from 500 grains. A less quantity than 350 grains in an adult of 150 pounds body-weight, who is eating the usual amount, should be regarded as pathological, and suspicious of renal insufficiency, or nephritis.
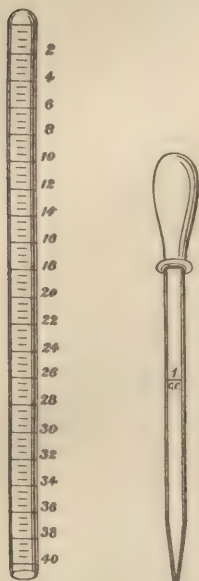
FIG. 73.—UREOMETER.

Uric acid, $C_5H_4N_4O_3$, is a constituent of normal urine, sometimes occurring in the free state, but oftener in combination with potassium, sodium, ammonium, and occasionally with calcium and magnesium, called collectively **urates.** For the description of this acid see page 466.

Uric acid is soluble in 14,000 parts of cold water, and is, therefore, frequently met with as a sediment, and is then detected by microscopical examination. In quantity it varies from 0.4 to 1.0 gm.

(from 6 to 15 grs.) in twenty-four hours. The ratio of uric acid to urea is about 1 : 40 to 1 : 50.

Detection.—It is best recognized, when in the free state, by the microscope. The crystals, as seen with this instrument, are colored yellow or reddish by the pigment uroxanthin, and appear in a variety of shapes, the most common being the "lozenge" or "whetstone" shape. They are sometimes large enough to be seen with the naked eye, when they appear as minute, garnet-colored grains, adhering to the sides or upon the bottom of the vessel.

Chemical Tests.—No. 1, Murexid Test.—Evaporate a portion of the urine to dryness in a porcelain dish upon a water-bath. Moisten the residue with nitric acid, and, after evaporating off the acid, moisten the residue with ammonium hydroxide. If uric acid be present, either in the free state or combined, the residue assumes a beautiful purple-red color, due to the formation of murexid. The reaction is said to occur also with xanthin, hypoxanthin, tyrosin, and some other bodies.

No. 2, Carbonate of Silver Test.—Render the urine decidedly alkaline with Na_2CO_3 or K_2CO_3, and moisten a filter-paper with the liquid. Now touch the moistened paper with a glass rod dipped in a solution of $AgNO_3$. A distinct gray stain indicates the presence of uric acid.

Estimation of Uric Acid.—The estimation of uric acid is usually attended with much difficulty and consumption of time. The author has devised the following volumetric method, which is fairly rapid, reasonably accurate, and requires little skill. It can therefore claim a place as a clinical method. The process is based upon the well-known fact that uric acid is completely precipitated from its solutions containing an excess of ammonium-magnesium mixture and ammonium hydroxide, by silver nitrate. When the precipitation is complete, the slightest trace of silver in solution is shown by the dark color produced in a drop of the clear solution by a soluble sulphide.

The solutions required are :

1. A $\frac{1}{50}$ normal solution of **AgNO₃**, made by diluting 1 volume of a $\frac{N}{10}$ solution with 4 volumes of distilled water.

2. **Magnesium mixture**, made to contain about 10 gm. of crystallized $MgSO_4$, 12 gm. of NH_4Cl, and 100 c.c. of aqua ammoniæ (U. S. P.).

3. A solution of **ammonium sulphydrate, or potassium sulphide**. This solution should be freshly made, and of such strength that its color is nearly that of the urine.

When the urine contains a sediment of uric acid, or acid urates, it is to be put in solution by warming with a few drops of NaOH solution before beginning the process, and the excess of alkali neutralized with acetic acid. In very dark fever-urines it is best to dilute with an equal volume with water. The titration is

performed in a hot solution, to prevent the precipitation of the xanthin bases by silver nitrate.

The process is conducted as follows: To 50 c.c. of the clear urine add 5 c.c. of the magnesium mixture and about 10 c.c. of ammonium hydroxide (sp. gr., 0.960), or enough to give a decided excess. Warm the solution on a water-bath, and add from a burette a $\frac{1}{50}$ normal solution of silver nitrate. From time to time a drop is removed from the solution, by means of a dropper-pipette, with a bit of absorbent cotton wound tightly over the end, so as to make an efficient filter, and after removing the cotton filter, bring a drop of the solution in contact with a drop of the weak potassium sulphide solution on a white porcelain surface. Experiments with pure water showed that it required $\frac{1}{2}$ c.c. of the silver solution in 50 c.c. to give a marked reaction. This amount must therefore be deducted from the reading. The titration is continued until a dark ring or cloud is seen at the line of contact of the two drops, showing the presence of silver in the solution. Each c.c. of silver solution corresponds to 0.00336 gm. of uric acid, and the number of c.c. used (less $\frac{1}{2}$ c.c. for each 50 c.c. of urine), multiplied by this factor, gives the number of grams of uric acid in the urine taken. From this we may easily calculate the amount in 100 c.c. or that excreted in twenty-four hours.

As soon as the process is complete, the precipitate rapidly settles, and it is best to draw off a drop or two from this clear supernatant liquid and test it carefully again. We may also check our work by running in another drop of the silver solution, to see if it produces a cloud, or to see if the precipitation be complete. As there is no excess of silver in the hot liquid at any time, there can be no reduction of silver.

If, after the titration is complete, the solution be cooled, it will usually be found that it will require from 1 to 3 c.c. of the silver solution to again produce the end reaction, because of the precipitation of the xanthin bases as silver compounds. The formula of the xanthin-silver compound is $Ag_2O.C_5H_4N_4O_2$. The factor for the $\frac{N}{50}$ $AgNO_3$ solution is 0.0015—that is, if we calculate them all as xanthin, each c.c. of silver solution used in the cold solution, more than is required by the hot solution, corresponds to the above amount of xanthin bases.

By making two titrations, the one in the hot and the other in the cold urine, we may estimate both the uric acid and the xanthin bases, the latter by the difference in the results of the two titrations.

ABNORMAL CONSTITUENTS OF URINE.

These are albumin, globulin, albumose, peptone, glucose, acetone, diacetic acid, bile-coloring matters, biliary acids, blood, blood-coloring matters, pus, chyle, and abnormal sediments, such as tube-casts, excessive amount of epithelium cells, mucus, etc.

Albumin.—Albumin is found in the urine, at times, without apparent disturbance of health. Usually, however, it is regarded as pathological, and is so often associated with various inflammatory diseases of the kidney that its presence is often taken as evidence of some one of these diseases. It occurs principally in the form of serum-albumin. It is coagulated by a temperature of from 73° to 75° C. (163.4° to 167° F.). In all cases the urine should be clear before applying the tests for albumin. If not clear, it should be either settled and decanted or filtered. It is sometimes necessary to shake the urine

with pulverized talc, or other powder, before filtering, to get it clear.*
The tests for albumin usually depend upon its coagulation and the
formation of a turbidity in the solution. A few tests depend upon a
change in color. The tests that are most satisfactory when applied to
the urine are as follows:

1. Heat about 5 c.c. of the urine to boiling in a test-tube. It is
then examined for even the slightest amount of turbidity. This tur-
bidity, if present, will be due to **albumin** or **earthy phosphates.**
Now add, slowly, a few drops of acetic or nitric acid. If the turbidity
be due to the phosphates, it disappears; while if due to albumin, it re-
mains permanent. Care must be taken, in the addition of the acid after
boiling, to note the effect after each drop is added, and to go on adding
until there can be no doubt that the urine is distinctly acid. This test
will show traces of albumin under the most favorable conditions.

2. **The Contact Method.**—Place 2 c.c. of pure HNO_3 in a
narrow test-tube, and, inclining the tube to one side, pour the urine
carefully down the side of the tube so that it may float upon the acid.
This is best done with a dropper-pipette, or by pouring the urine from
one test-tube into another, holding both in a nearly horizontal position.
If this be done carefully, there will be very little admixture of the two
liquids. If albumin be present, a white, opaque zone of coagulated
albumin appears at the line of contact of the two fluids. A brown
zone will frequently be seen at this point, which grows in intensity on
standing, and is due to the action of the acid on the coloring matters,
but it does not give any turbidity unless albumin is present. If bile
be present, the color may be green; if blood, brown-red. This test
is decidedly more delicate than No. 1.

Precautions.—Occasionally after the administration of turpentine,
or balsams and resins, these are precipitated by HNO_3 as a yellow-
white cloud, which, however, is soluble in alcohol. I have never seen
the uric acid, sometimes set free by HNO_3, resemble the precipitated
albumin nearly enough to be mistaken for it. Roberts modifies this
test by using, instead of pure nitric acid, a mixture of 1 volume of HNO_3
and 5 volumes of a saturated solution of $MgSO_4$. This reagent is as
sensitive as HNO_3, and pleasanter to handle. It is used in the same way.

3. **Acetic Acid and Potassium Ferrocyanide.**—Acidulate
the urine with acetic acid, filter if much mucin is precipitated, and
then add a few c.c. of a solution of potassium ferrocyanide. Or,
better, float the acidulated urine over the K_4FeCy_6 solution. If albu-

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* Turbid urines may be rendered clear by adding a few drops of $MgSO_4$ solution,
then an excess of NH_4OH, and filtering from the phosphates. The urine is then
acidified with acetic acid.

min be present, it appears as a white precipitate. This reagent does not precipitate peptone, mucin, or alkaloids. It is a very delicate and reliable test.

4. **Picric Acid with Acetic Acid.**—A cold, saturated solution of picric acid may be used by the **contact method,** after previous acidulation of the urine. At the line of contact the albumin appears as a white zone. Heat afterward to dissolve alkaloids, mucin, peptones, and urates, which are precipitated with the albumin. It is better to heat the urine before adding the test solution.

5. **Sodium Tungstate Solution.—Reagent :** Made by mixing equal parts of cold, saturated solutions of sodium tungstate and citric acid. As its specific gravity is heavier than that of urine, it is best applied by the contact method, adding the reagent first. This is an extremely delicate test, and precipitates at the same time peptones, mucin, some alkaloids and urates, all of which, except mucin, are dissolved by heating.

6. **Tanret's Test (Potassio-mercuric Iodide Test).**—Reagent prepared as follows : Mercuric chloride, 1.35 gm. ; potassium iodide, 3.32 gm. ; acetic acid, 20 c.c. ; distilled water, 80 c.c. The $HgCl_2$ and KI are separately dissolved in water and then mixed, and the acetic acid afterward added. The resulting liquid is heavier than urine (sp. gr., 1040), and is best used by the contact method. It is exceedingly delicate, detecting 1 part of albumin in 20,000 parts of urine. Heat to dissolve the alkaloids, mucin, and peptone, as in tests 4 and 5.

Jolles suggests the following very delicate reagent : Mercuric chloride, 10 ; succinic acid, 20 ; sodium chloride, 10 ; distilled water, 500.

7. **Acidulated Brine Test.—Reagent :** To a pint of a saturated solution of common salt add 1 ounce of HCl, and filter if necessary. This is a delicate test for albumin when properly used. It has a high specific gravity, and is best used as follows : The solution is heated to boiling, and the urine added by the contact method. If albumin be present, it appears as a zone at the contact surface. It does not precipitate peptone, albumose, or the alkaloids.

8. **Trichloracetic Acid.**—This is a white, crystalline acid, sometimes employed as a test for albumin. It may be used in the form of a saturated solution by the contact method, or the crystals may be added directly to the urine, when they will form a strong solution at the bottom of the tube. It presents no decided advantages over the tests above mentioned.

9. A solution of **salicyl-sulphonic acid** in water, or the crystalline acid added directly to the urine, is a very delicate test for all forms of albumin, precipitating albumoses and peptones, but not alkaloids or mucin. The albumoses and peptones dissolve on heating, to

reappear on cooling. A large excess of mucin, or nucleo-albumin, may give a cloudiness with this reagent. It is a white, crystalline acid, formed by saturating strong H_2SO_4 with salicylic acid, and setting aside to crystallize.

10. **Metaphosphoric** or **glacial phosphoric acid** has also been recommended by some as a reliable test for albumin in urine. A solution of **resorcinol** in water ($1 : 3$) has also been highly recommended.

Albumin test-papers, suggested by Dr. Oliver, may be prepared by saturating bibulous paper in solutions of potassiomercuric iodide, of potassium ferrocyanide, and of citric acid. To use these papers the urine is acidified with one of the citric acid papers, and then either a potassiomercuric iodide or a potassium ferrocyanide paper added.

The **quantitative** estimation of albumin is of considerable importance, but somewhat difficult to perform. Comparative tests are all that the clinician will usually find necessary. The easiest approximate method is to boil a given quantity of the urine in a test-tube, add 2 or 3 drops of nitric acid, set aside for twelve hours, and note the volume occupied by the precipitated albumin. This is generally spoken of as **volume per cent., and has no relation to actual percentage.**

A more accurate method, and one sufficiently so for clinical purposes, is with **Esbach's albuminometer.** This consists of a graduated glass tube, shown in figure 74. To use the instrument, fill to U with urine, and to R with the test liquid. Close the tube by a rubber stopper, mix by agitation, and set aside for twenty-four hours. Each of the main divisions which the precipitate covers represents 1 gm. of albumin in 1 liter of urine.

FIG. 74.

Test solution : Picric acid, ... 10 gm.
Citric acid, ... 20 gm.
Water, ... 1000 gm.

Comparative tests may be made by adding any of the above reagents to a measured volume of urine, and then placing the tube in the centrifugal machine, separating the coagulated albumin and measuring its volume.

Densimetric Method.—Acidify the urine with acetic acid ; take the specific gravity as accurately as possible, noting the temperature. Coagulate the albumin by boiling, and filter from albumin. Bring the filtrate to the same temperature as before, and take the specific gravity again. The difference in specific gravity degrees, multiplied by 0.4,

gives the grams in 100 c.c. of urine. Or, a difference of one degree in specific gravity gives 0.400 gm. albumin in 10 c.c. of the urine. It will be seen, therefore, that the specific gravity should be very accurately taken with the picnometer.

Serum-globulin, or **paraglobulin,** is usually associated with serum-albumin, from which it may be separated. It may be detected in the urine as follows : To a large volume of water in a beaker or urine-glass let fall a few drops of albuminous urine. If globulin be present, each drop as it falls will be followed by a milky train, which, when enough is added, forms an opalescent cloud in the water. The addition of acetic acid dissolves this cloud. This test depends upon the fact that globulin is soluble in a weak solution of sodium chloride, such as urine is, but on greatly diluting this solution the globulin becomes insoluble. It is, therefore, precipitated by diluting the urine until the specific gravity is 1002 to 1003.

It may be precipitated by rendering the urine slightly alkaline with NH_4OH, filtering to separate the phosphates, and adding to the filtrate an equal volume of a saturated solution of ammonium sulphate. If a precipitate forms, it is globulin. It occurs with serum-albumin, and rarely without it. It is most abundant in lardaceous kidney, in some cases of acute nephritis, and in the temporary albuminuria of disordered digestion.

Albumoses, or Propeptones.—To test for albumose it is best to first remove the albumin. This is best done by acidifying the urine with a few drops of acetic acid and adding about one-third its volume of a saturated solution of common salt, boiling and filtering. Albumin and globulin are thus removed. The filtrate is allowed to cool, and any turbidity which separates on cooling, or after the further addition of the salt solution, and which disappears by heating to reappear again on cooling, is albumose or propeptone.

Or, after the removal of the albumin and globulin as above, the solution may be saturated with ammonium sulphate, when albumose, if present, will be precipitated. The only disease with which it appears to be associated is osteomalacia.

Peptone.—Peptone is not present in normal urine, but is occasionally found, either with or without albumin. Peptone differs from albumin and albumoses, in that it is not precipitated by tests Nos. 1, 2, 3, 7, and 8, but is precipitated from a cold solution by Nos. 4, 5, 6, and 9, and by tannin, phosphotungstic acid,* and Millon's reagent. When

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* Phosphotungstic acid is made by adding H_3PO_4 to a hot solution of sodium tungstate till decidedly acid. Cool, and render strongly acid with acetic acid or HCl. Filter after standing over night.

precipitated by tests 4, 5, 6, and 9, it is dissolved when the solution is warmed, and separates again as it cools. Peptone gives with the biuret reaction a rose-red color, while albumin gives a purple or blue.

Tests for Peptone.—These all require previous treatment of the urine. If albumin be present, it should first be removed, either by saturation with ammonium sulphate and filtration, or by the addition of acetic acid and potassium ferrocyanide, and filtering. It is usually desirable to decolorize the urine by the addition of a solution of lead acetate, as long as it produces a precipitate, and filtering. This treatment is not always necessary. The test may now be applied to this filtrate. Phosphotungstic acid, acidulated with acetic acid, added to this filtrate, or to the solution from which other proteids have been removed, will precipitate peptone, if present; but if it be present in small quantities, the cloudiness appears only after five to ten minutes.

A less sensitive test than the above is made by floating the urine upon some Fehling's test solution. At the point of contact, a delicate rose-red zone will indicate peptone. When positive, this test is valuable; but when negative it will not prove the absence of traces of peptone.

The presence of peptone in the urine, although it is not positively settled, is believed to be due in most cases to the disintegration of pus-corpuscles somewhere in the body, and the absorption of the decomposition products. It is found in many of the acute fevers and in many acute suppurative processes. It may serve to indicate whether a pleuritic effusion is purulent or not, and to distinguish tubercular from epidemic cerebrospinal meningitis, as the latter is usually attended with peptonuria, while the former is not.

Mucin, or Gluco-proteids.—Mucin is secreted by the healthy mucous membranes. It can not be regarded, therefore, as abnormal in the urine until it is present in increased amount, and then it indicates an irritated or inflamed condition of the membranes of the urinary tract. It is not precipitated from its solutions by boiling, but is precipitated by alcohol, dilute mineral acids, acetic, picric, and citric acids. It is best detected, in clear urines, by its forming a sediment on standing, which floats as a translucent cloud near the bottom of the containing vessel, but not upon it. It may also be detected by floating the urine upon a solution of citric or acetic acid, when just above the line of contact a somewhat indefinite zone or coagulum gradually makes its appearance. Albumin, when present, is not precipitated by these acids without the application of heat.

We may also precipitate mucin by the addition of about two parts of alcohol to one part of urine, when mucin and any albuminoid bodies present will precipitate. The precipitate may be filtered out,

washed with alcohol, and the mucin dissolved out with warm water, or lime-water, when it may be precipitated from the filtrate again with alcohol or the dilute acids.

Accidental Albuminuria.—Whenever the urine contains blood, pus, or serous discharges it will of necessity contain albumin. **Fibrin** will be found when there are hemorrhages from the genito-urinary passages, and in intense or acute inflammations of the kidneys. It also occurs in the urine of most cases of chyluria. It is readily recognized by its spontaneous coagulation, forming a thick, gelatinous, glairy mass, separating at the bottom of the containing vessel. The coagulum may be filtered out and its solubility determined. If insoluble in dilute alkalies and ten per cent. NaCl solution, it is fibrin.

Blood.—The presence of **blood** may be detected most readily and certainly by the microscope, when the red blood-corpuscles may readily be seen.

Guaiacum Test for Blood.—Mix a small portion of the urine in a test-tube with an equal volume of a mixture of freshly prepared tincture guaiacum and spirits of turpentine. The turpentine should previously have been exposed to the air for some time. If blood-coloring matter be present, the mixture assumes an indigo-blue color, whose rapidity of formation and depth of color depend upon the amount of blood-coloring matter present. Pus frequently, if not always, gives the same color. Saliva and salts of iodine also give a blue color with this test, but the color due to these substances appears only after a considerable lapse of time, and is seldom likely to mislead. From the depth of the color of the urine, and the rapidity of the appearance of the blue color, one can judge of the relative amount of blood present. The spirits of turpentine used in this test may be replaced by a solution of peroxide of hydrogen, or a mixture of ether and H_2O_2 (ozonic ether).

Having determined that blood is present in the urine, it is a difficult matter to decide whether the albuminuria is due entirely to the albumin introduced with the blood, or whether it is a true albuminuria of renal or inflammatory origin. This will often depend upon other symptoms than those to be found in the urine. Dissolved blood-coloring matter is sometimes met with in the urine, when it is called **hemoglobinuria**. In hemoglobinuria, blood-corpuscles are not to be found with the microscope, while in **hematuria** the corpuscles are found. It occasionally happens that the urine rapidly becomes alkaline after being secreted, and the red blood-corpuscles are disintegrated and dissolved by the alkaline urine. The urine containing the dissolved corpuscles is then always alkaline, while the urine of true hemoglobinuria is usually acid. We may conveniently distinguish, then, two conditions: In one, the blood-coloring matter is in solution, and in the other it is in suspension as blood-corpuscles. In the former case the coloring matter will not separate on standing, while in the latter there will usually separate, within a few hours, a more or

less abundant red sediment. If the hemorrhage be a profuse one, especially if from the bladder or ureters, the blood will almost all of it settle to the bottom of the containing vessel, and leave a clear yellow, almost normal-looking urine above; while if the hemorrhage be a gradual oozing, as in acute inflammation of the kidneys, the coloring matter will remain in suspension and the liquid retain its color for many days. It is not unusual to have hemoglobinuria and hematuria together, especially in acute diffuse nephritis, or in malarial hematuria.

If we add an alkali to urine containing blood, the earthy phosphates are precipitated, carrying down with them the blood-coloring matter and forming a blood-red deposit. By the application of heat the sediment deposits more rapidly, and the solution may assume a green color. If the urine is already alkaline, and the phosphates have separated out, we can produce a precipitate for the purpose of carrying down the blood-coloring matter by the addition of a few drops of a solution of $MgSO_4$. **Hemin crystals** may be prepared from the above precipitates, by spreading a small portion of them upon a glass slide, and treating this with a crystal of common salt and a drop or two of glacial acetic acid, covering with a cover-glass, warming it gently, and examining, after a few hours, with the microscope. The crystals appear as small, oblique plates of a dark-red or brown color. They are easily recognizable by a good $\frac{1}{4}$-inch lens.

Pus.—If the urine contains **pus** it will always be turbid to the naked eye, and rapidly deposit a white or greenish-white sediment. The clear solution will be found to contain albumin and globulin. The application of heat to the sediment does not dissipate it, as it does the sediment of urates. Neither is it dissolved by dilute acids, as is the somewhat similar-looking precipitate of the earthy phosphates. A whitish sediment, therefore, which is insoluble with heat or dilute acids, and which dissolves in strong alkaline solutions, giving a gelatinous, ropy liquid, is probably pus. (Donné's test.) When pus is treated with a solution of hydrogen peroxide it undergoes rapid effervescence. This is a valuable test for pus in the urine or in other fluids. The microscope is a more certain test for pus. Having detected pus in the urine, it is sometimes very difficult to determine whether the albuminuria accompanying it is accidental—*i. e.*, whether the albumin is derived from the pus, or whether there is a true albuminuria due to some disease of the kidney. The symptoms of the patient will assist in determining in many cases, though not in all.

Sugar.—It has been claimed by many that dextrose occurs in normal urine, and it has been disputed by equally good authority. The most delicate tests do detect glucose in most urines otherwise normal, though not in all. Suffice it to say, that the usual tests, and those here mentioned, except Molisch's, will not detect this substance

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in normal urine. Its appearance, then, in sufficient quantities to be detected by any of them must be regarded as abnormal.

When glucose occurs in the urine in an appreciable amount, it is known as **glycosuria.** When its occurrence persists for a considerable time and in considerable amount, and is attended with an increased amount of a light-colored urine, generally of a high specific gravity, and an increased daily excretion of urea, it is pathological, and the disease is known as **diabetes mellitus.** The specific gravity is some guide to the detection of diabetes mellitus, but the specific gravity alone is not conclusive. A high specific gravity, with a large quantity of light-colored urine, is strong presumptive evidence of diabetes mellitus. The finding of sugar in such a case is confirmatory. The detection of sugar in the urine is a comparatively simple process.

Tests for Glucose.—Trommer's Test.—To 4 or 5 c.c. of urine, in a test-tube, add one-half its volume of sodium hydroxide solution, and 1 or 2 drops of a solution of $CuSO_4$ (1 to 10). If sugar be present, a clear, deep-blue color is obtained. If an excess of copper sulphate be added, a clear solution may not be obtained, and will, in this way, disturb the test. The solution is now to be heated almost to boiling, but it is better not to boil. If sugar be present, at first a greenish and then a yellowish turbidity forms, which rapidly changes to a reddish-yellow color, and precipitates red cuprous oxide. A flocculent precipitate of the earthy phosphates always forms on adding the alkali, and must not be mistaken for suboxide of copper. Urine containing uric acid, the xanthin bases, creatinin, indoxyl-sulphates, peptone, lactose, glycuronic and glycosuric acids, mucus, and other substances found in some urines will decolorize the blue solution, but there will be no red precipitate. In fever urines, this decolorization without precipitation interferes greatly with the employment of this test. It is, therefore, not to be relied upon in doubtful cases.

To eliminate this source of trouble with the copper test, it is best to use a solution of the acetate of copper, or sodium acetate added to the sulphate, to precipitate the uric acid, xanthin, hypoxanthin, and the most of the creatinin and phosphates, filter, and apply the test to the filtrate.

From 7 to 8 c.c. of the urine are heated to boiling in a test-tube, and, without filtering from any precipitate that may form, adding 1 c.c. of the copper sulphate solution; then, when partially cooled, 1 to 2 c.c. of a saturated solution of sodium acetate, having a slight acid reaction, and filter. To the filtrate, which should have a greenish-blue color, add the alkali, or, better, the alkaline tartrate solution used to make Fehling's solution, and boil for fifteen to twenty seconds. Thus modi-

fied, the copper test is much more reliable. Most of the interfering substances may be separated by adding to the hot urine one-fourth its volume of a 10 per cent. solution of lead acetate, filtering off the precipitate, and testing the filtrate for sugar.

2. **Other Forms of the Copper Test.**—Haines' solution is made by dissolving copper sulphate in a mixture of equal quantities of glycerin and water. This solution may be used in larger quantities than the aqueous solution of copper used in Trommer's test, and some of the difficulties of that test overcome. The decolorizing effect of normal urine is not sufficient to decolorize a large amount of copper solution. By adding a considerable amount of Haines' solution before heating, this error is partially eliminated. **Fehling's solution** is sometimes employed as a qualitative test, but usually only as a quantitative test; Haines' solution has all the advantages of Fehling's, with the additional advantage that it keeps well.

3. **Bismuth Test.**—To a few c.c. of the urine, in a test-tube, add an equal volume of sodium hydroxide, and then a fragment of bismuth subnitrate; mix well and boil for from three to five minutes. If sugar be present, black metallic bismuth will be deposited as a sediment. If the quantity of sugar be small, only a part of the bismuth will be reduced, and the precipitate will appear gray. Albumin must be removed before this test is applied, or it will be decomposed by boiling with the alkali, forming the sulphide of bismuth, which will give a black precipitate.

4. A better form of this test is as follows: A solution is made of bismuth subnitrate, 2 gm.; Rochelle salt, 4 gm.; sodium hydroxide, 8 gm.; and distilled water, 100 c.c. The urine is heated to boiling and a few drops of this alkaline solution of bismuth added, and, on continuing the boiling, if sugar be present, the mixture turns black. As in the previous test, albumin must be absent before this test is applied. This reagent is exceedingly delicate, and it is claimed to detect 0.025 per cent. of glucose.

5. **Picric Acid Test.**—To about 5 c.c. of urine add one-half as much of picric acid solution (as in testing for albumin), and then 2 c.c. of sodium hydroxide, and boil. If sugar be present, a dark, mahogany-red color is developed. If no sugar is present, a dark hue is developed before boiling, but not the dark color above described. If albumin be present, a turbidity will form on the addition of the picric acid, but it does not interfere with the test.

6. **Moore's Test.**—Add to the suspected urine one-half its volume of sodium hydroxide solution, and boil. If sugar is present, a dark-yellow, brown, or chocolate color is produced. The depth of color is proportional to the amount of sugar present.

7. **Indigo-carmine Test.**—**Reagent** : Mix 1 part of indigo-carmine, or of dried commercial extract of indigo, with 30 parts of pure, dry sodium carbonate. To 5 c.c. of the suspected urine add enough of the above powder to give a transparent, blue solution, and heat to boiling *without agitation*. If sugar is present, the solution changes to violet, cherry-red, and finally yellow. On agitation, these colors appear in the reversed order.

Instead of extract of indigo, a solution of sulphate of indigo with an excess of sodium carbonate may be employed. None of the ordinary constituents of the urine affect this test, while many substances occurring in the urine affect Fehling's solution. Many other substances which reduce the alkaline copper solution do not affect the indigo-carmine test. In careful hands it is to be recommended as a sensitive and reliable test for glucose in the urine.

8. A solution of **methylene-blue** (0.333 gm. per liter) has been used as a test for sugar. Five c.c. of this solution are mixed with 2 c.c. of sodium hydroxide, 2 c.c. of urine added, and the solution is boiled for one minute. If sugar be present, the blue color is discharged, but returns on standing.

9. **Safranin** is another coloring matter used as a test for sugar. Mix equal volumes of sodium hydroxide, safranin solution (1 gm. to the liter of water), and the urine, and heat to boiling. If sugar be present, the red color is changed to a yellow. Uric acid, creatin, creatinin, chloral, and chloroform do not give the test. Albumin must be removed. The test seems reliable.

10. **Phenyl-hydrazin Test.**—For the details of this test see **glucose,** in part v of this book.

11. **Alpha-naphthol Test.**—**Molisch's Test.**—To 1 c.c. of the urine add 2 c.c. of a 10 per cent. solution of a-naphthol in pure methyl- or amyl-alcohol, and after mixing add an excess of H_2SO_4. If sugar be present, a deep-violet color is developed. On dilution with water a blue precipitate occurs, which is soluble in alcohol, ether, and potassium hydroxide, to give a yellow solution. If, instead of naphthol, we use thymol or menthol, a deep-red color is produced, which gives a carmine-red, flocculent precipitate on dilution, which dissolves as above with the formation of a yellow solution. This test is exceedingly delicate, and reacts with most sugars and glucosides. Urea, indican, creatinin, xanthin, uric acid, hippuric acid, phenol, and pyrocatechin give negative results. As many normal urines respond to this test, Molisch concludes that they contain sugar.

The Quantitative Estimation of Dextrose.—This is generally made with Fehling's solution. This solution is best prepared in two parts, which are kept separately, as the completed solution does not

keep well. These solutions are prepared as follows: No. 1. 34.639 gm. of pure, recrystallized copper sulphate are dissolved in distilled water, and made up to exactly 500 c.c. No. 2. 175 gm. of crystallized Rochelle salt and 60 gm. of sodium hydroxide are dissolved in distilled water and made up to exactly 500 c.c. When needed for use, exactly equal volumes of these two solutions are mixed. The solution will be of such strength that 10 c.c. are decolorized by 0.050 gm. of dextrose or diabetic sugar.

The process is conducted as follows: Ten c.c. of Fehling's solution are measured out into a beaker or porcelain basin, diluted with about 40 c.c. of water, and brought to the boiling point. The urine is delivered into this blue solution from a burette, until the blue color is just discharged. The amount of urine added is then read off from the burette, and this amount contains 0.050 gm. of sugar. From this it is easy to calculate the quantity contained in 1000 c.c., or a liter. If the urine contains a considerable quantity of sugar, it will be necessary to dilute it with four volumes of water before beginning the titration, when the results of the titration should be multiplied by five. It is always somewhat difficult to determine the exact disappearance of the blue color, owing to the presence in the solution of the precipitated suboxide of copper. This difficulty may be overcome by the addition of some substance that will prevent the precipitation of the cuprous oxide, as NH_4OH, KCy, or $K_4Fe(CN)_6$.

The **author's method** is as follows: Ten c.c. of Fehling's solution are measured out into a suitable flask. To this 10 c.c. of a freshly prepared 10 per cent. solution of potassium ferrocyanide are added, and about 30 c.c. of water. The mixture is heated on a water-bath, and the urine, previously diluted with water, if it contains much sugar, is run in from a burette, drop by drop, until the blue color just disappears. This can readily be seen, as the solution remains clear to the end of the reaction. The addition of the slightest excess of sugar shows itself by the solution becoming quickly brown. By careful comparative tests the author has found this method to be accurate, reliable, and rapid, provided the solution be not boiled during the reduction. The best temperature for the process was found to be between 80° and 90° C. (176° to 194° F.).

Estimation by the Polariscope.—This is a convenient and rapid method for the determination of glucose, when the quantity exceeds 1 per cent., and when all the appliances are at hand, which is seldom the case except in well-equipped laboratories. The method, briefly, is as follows: The suspected urine, freed from albumin, is treated with a solution of basic lead acetate, in the proportion of 1 to 10 of the urine, and filtered. The observation-tube of the polariscope is

filled with this fluid, when it is placed in position, and the rotation determined.

The readings must be increased by one-tenth (allowance for the lead acetate solution).

The specific rotatory power of dextrose is $+52.5°$. (See p. 52.)

The weight of the sugar in the solution will be given by the formula : $W = \dfrac{a}{52.5 \times 1}$; in which $a =$ observed rotation, l the length of the tube in decimeters, and W the weight of sugar in 1 c.c. of the solution.

Suppose, in a given case, the rotation observed was $4°$, after allowing for the lead solution, and the length of the observation tube was two decimeters. We then have $W = \dfrac{4}{52.5 \times 2}$, or $\dfrac{2}{52.5} = 0.038$ gm. in 1 c.c. of urine, or 3.8 per cent.

As levulose sometimes occurs with dextrose in cases of diabetes, and as it will rotate the plane of polarized light to the left instead of to the right, and, in fact, as there are a number of substances likely to occur in the urine which rotate the plane of polarized light, this method of determining sugar is not free from error.

Lactose, or **milk-sugar,** occurs in the urine of nursing women or of women soon after weaning. Its recognition requires first its separation from the fluid.

Dextrin has been found in the urine of diabetics, where it seems to take the place of dextrose. Other carbohydrates found rarely in the urine are pentoses, maltose, and animal gum.

Acetonuria.—Normal urine contains traces of acetone, but it occurs in excessive quantities as a pathological condition. It is found in many of the fevers, certain forms of cancer, in starvation, and in certain nervous troubles accompanying diabetes. The commonest of these is febrile acetonuria. The appearance of acetone in diabetes indicates an advanced stage of the disease, but it decreases in diabetic coma. It is always associated with an increased proteid metabolism, and is looked upon as a product of proteid decomposition with deficient oxidation. It is closely allied to certain other substances found in some urines. These are hydroxybutyric acid, aceto-acetic acid, also called diacetic acid. The following formulæ will show the relations of these bodies :

Hydroxybutyric acid, ... CH_3—CH(OH)—CH_2—COOH.
Aceto-acetic acid (diacetic acid), ... CH_3—CO—CH_2—COOH.
Acetone (dimethyl-ketone), ... CH_3—CO—CH_3.
Aldehyde, ... CH_3—COH.
Acetic acid, ... CH_3—COOH.
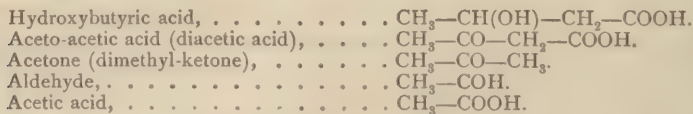
Detection.—Legal's Test.—Four or five c.c. of the urine are treated with a few drops of a freshly made solution of sodium nitroprusside, and then with a strong solution of NH_4OH. The red color produced, which appears in from five to ten minutes of acetone be present, gives place to a purple or violet color on the addition of acetic

acid. For a more accurate test it is necessary to distil the urine, and apply this or the following test to the distillate :

Lieben's Test.—To several cubic centimeters of the distillate add a few drops of a solution of iodine in potassium iodide, and then a solution of KOH. If merely a trace of acetone be present, a precipitate of iodoform crystals is deposited. This test is reliable and delicate in the absence of lactic acid and alcohol, but if NH_4OH be used for the KOH, alcohol will not form iodoform, while the acetone will do so.

Diacetic acid appears in the urine of diabetics and of certain fevers, and is always an abnormal constituent. It is most common in the contagious fevers of childhood, and in such cases has little significance ; but in adults it is a grave symptom, as it usually precedes the advent of coma. It usually occurs together with acetone, and in the presence of ferric chloride produces a wine-red color, which is not entirely characteristic, because other substances produce the same color. The following process will serve for its detection : A fairly strong solution of ferric chloride is cautiously added to the urine, and if a phosphate precipitates, this is removed by filtration, and more Fe_2Cl_6 added to the filtrate. If a red color appears, it is divided into two portions. One portion is boiled, whilst the other is treated with H_2SO_4, and extracted by shaking with ether. Urine that has been boiled loses its red color, this color being destroyed by boiling. After treatment with H_2SO_4 and shaking with ether, the aceto-acetic acid will be found in the ether. The ether may now be evaporated, and the residue treated with Fe_2Cl_6 solution, when the violet-red color will be obtained if it be present. The urine for this test must be fresh, as diacetic acid is rapidly converted into acetone on standing. Acetone is an oxidation product of diacetic acid. If the quantity of acetone be large, it may cause toxic symptoms.

Hydroxybutyric acid is found in the blood of diabetic patients, and its oxidation produces diacetic acid. The relation of these three bodies is then oxybutyric acid, diacetic acid, and acetone, in the order named. It gives the same color-reaction with Fe_2Cl_6 as diacetic acid. It is best to separate it from the urine with ether, as above described for diacetic acid, before applying the test.

Lipaciduria is a term which has been applied to the condition in which volatile fatty acids are found in the urine. These occur normally in traces, especially formic, acetic, and butyric acids. As a symptom of disease, however, they are of no significance. Formic, acetic, propionic, and butyric acids have occasionally been detected in the urine of fevers, in certain diseases of the liver, and in diabetes. For their detection the urine is distilled with phosphoric acid, and the test applied to the distillate. For simpler tests we may apply the following : Acetic acid may be detected by the odor of acetic ether when the distillate is warmed with alcohol and sulphuric acid. Ferric chloride gives a red tint, which disappears on boiling if acetic acid is present. Formic acid gives a white precipitate with silver nitrate, which blackens on warming.

Fat.—Fat occasionally occurs in the urine, and gives to it a more or less turbid appearance, which clears on shaking the solution with ether. On separating and evaporating the ether, the fat remains behind. In chyluria the opacity is due both to the fat and to albuminous substances in imperfect solution. In some cases the appearance of this turbidity is intermittent, appearing only at certain times of the day ; in others it is constant. In some cases chylous urine deposits a spontaneous clot of fibrin, while in others it does not. The fat may be separated by extraction with ether, but the turbidity still remains.

In some rare cases, however, the turbidity disappears with the extraction of the fat.

Detection.—Its detection is usually sufficiently easy from the milky-white color, and the separation of the fat on standing. Microscopically, the fat globules can be detected in some cases, but in others the microscope fails to reveal them. The author has seen a case where they were not visible with a $\frac{1}{16}$-inch objective.

Bile.—Urine containing bile usually has an abnormal color—either a brilliant yellow, a greenish-yellow, or brown. When the bile is abundantly present, the froth or foam produced on shaking the urine is quite permanent, and is more or less colored. A piece of filter-paper or linen moistened with such urine retains the yellow color on drying.

Gmelin's Test.—Upon 1 or 2 c.c. of a partially decomposed yellow nitric acid, in a test-tube, carefully float 4 or 5 c.c. of the suspected urine. If bile-coloring matters be present, a succession of colors will appear in the urine, beginning with green, then passing through blue, violet, red, and yellow, the green appearing at the top and the others below, in the order named. The green color is always present when bile is present, but the reddish-violet color must not be taken for evidence of bile, as the normal coloring matters of the urine may produce such a coloration.

If the decomposed nitric acid, or nitrous acid, be not at hand, it may readily be prepared by adding a fragment of zinc to ordinary pure nitric acid. This test may also be applied as follows: The urine may be mixed with a concentrated solution of sodium nitrate, and the mixture floated upon sulphuric acid, when the play of colors will be obtained as before; or a crystal of sodium nitrate may be dropped into strong sulphuric acid, and the urine floated upon this.

Tincture of Iodine Test.—Upon the surface of the urine in a test-tube, float a few drops of tincture of iodine. At the line of contact of the two fluids there appears, after a few minutes, a beautiful emerald-green zone when biliary coloring matters are present. This test seems to be delicate and reliable.*

Biliary Acids.—While the acids usually occur in the urine of jaundiced patients, along with the coloring matters, their detection is not so easy. We may use the following test: Evaporate the liquid to dryness, and treat the residue, consisting of biliary salts, with alcohol, and filter. After evaporating the alcohol, apply Pettenkofer's test (see p. 468) to a solution of the residue in water. **Dr. Oliver's**

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* Jolles says that antipyrin in urine gives a similar green color.

peptone test is, however, applicable to urine. The reagent is pre-
pared as follows: Pulverized peptone, 2 gm.; salicylic acid, 0.250
gm.; acetic acid, 2 c.c.; distilled water, sufficient to make 250 c.c.
The urine, rendered perfectly clear by filtration, is rendered acid and
diluted until the specific gravity is 1008. One c.c. of this diluted
urine is run into about 4 c.c. of the above test solution. If biliary
salts are present, a distinct milkiness promptly appears, but it becomes
more intense in five minutes. Albumin, if present, should be sepa-
rated before the application of this test. The test is very delicate,
and apparently reliable.

Diazo-reaction.—This reaction is one that is obtained in the urine of persons
suffering from certain specific fevers, especially typhoid fever, measles, septicemia,
and in some cases of phthisis. The reagent is made as follows: One gm. of sulph-
anilic acid is dissolved in a mixture of 350 c.c. of water and 15 c c. of hydrochloric
acid. A second solution is made by dissolving 0.5 gm. of sodium nitrite in 100 c.c.
of water. Five c.c. of urine are mixed with an equal volume of sulphanilic acid
solution, and then with 3 or 4 drops of the sodium nitrite solution, and, finally, 10
drops of ammonia water. Normal urine shows with this test a yellow or orange
color, and a precipitation of phosphates. In certain of the above-named diseases,
especially in typhoid, the urine gradually assumes a carmine-red color. The froth
produced on agitation is also distinctly red, and the precipitated phosphates show a
green or violet color. Many phenol derivatives give a similar color-reaction with the
above test, and may lead to erroneous conclusions. According to Ehrlich, this reac-
tion is characteristic of the urine in typhoid, measles, and acute tuberculosis. Others
deny the value of the test, the difference being possibly due to the interference of
phenol derivatives.

Ferments Found in the Urine.—Pepsin, trypsin, and a diastasic ferment have
been found in the urine, in addition to the organized ferments of lactic, butyric, and
acetic acids, and urea. The pepsin ferment of the urine is said to be absent in the
urine of typhoid fever, carcinoma of the stomach, and, according to some, in
nephritis.

Detection.—Pepsin is best detected by Sahli's method. A little pure fibrin is
placed in the urine and set aside for several hours. It is then removed, placed in
diluted HCl (0.2 per cent.), and the mixture kept at a temperature of from 30° to 40°
C. (86° to 104° F.). Any pepsin present in the urine is taken up by the fibrin, and
the latter is slowly digested in the acid fluid.

The diastasic ferment is detected in the usual manner by its effect upon starch-
mucilage. The milk-curdling ferment has occasionally been found in the urine. (See
also Organized Ferments. p. 557.)

Ptomaines, or diamins, have been found in healthy urines as well as in morbid
urines. In most fevers, especially in the specific and contagious fevers, the urine
contains certain poisonous alkaloids. These can be detected by first acidifying the
urine and filtering from any mucus present, and then precipitating with the double
iodide of potassium and mercury. The precipitate, which contains these bases, is
distinguished from albumin or other substances by its solubility in alcohol at a gentle
heat.

The diamins of the urine may be precipitated as benzoyl compounds by benzoyl
chloride and caustic potash. By this means cadaverin, putrescin, and other diamins
have been detected in the urine of vesical catarrh. Normal urine is said to be free
from these bodies.

URINARY DEPOSITS OR SEDIMENTS.

Normal urine is clear, but on standing it will usually deposit more or less sediment. Urine that is turbid when passed will usually deposit a sediment, which may contain mucus, pus, blood, chyle,
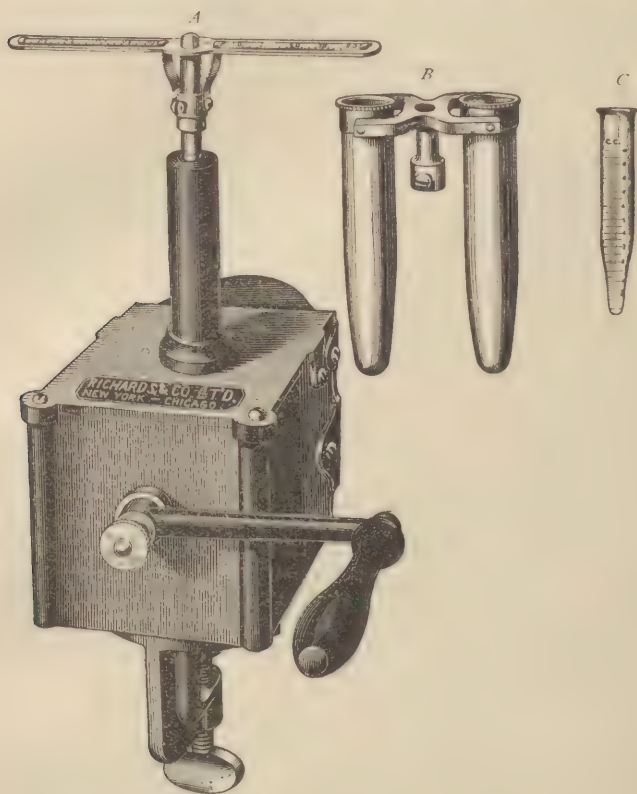
FIG. 75.

earthy phosphates, acid urate of sodium, or an abundance of epithelial cells from the kidney, ureters, or bladder. A turbidity which appears within a few hours after the urine is voided is most likely to be due to acid urates, the oxalate of lime, or the earthy phosphates. When

such a deposit is to be examined, a few ounces of the urine are set aside in a cylinder or tall vessel to allow the sediment to accumulate, or, better, the sediment may be separated from the fresh urine by the centrifugal machine. The urine to be examined is well shaken and poured into specially constructed tubes (*C*, figure 75); these are placed in the receptacles (*A*) and revolved. The sediment forms at the bottom of the tube. This is more satisfactory than spontaneous sedimentation, because some sediments undergo changes on standing in contact with urine. The usual form of centrifuge is shown in figure 75. It requires from three to four minutes to obtain a complete sedimentation of ordinary urine. The sediment may be removed from the solution by means of a pipette, or narrow glass tube, by
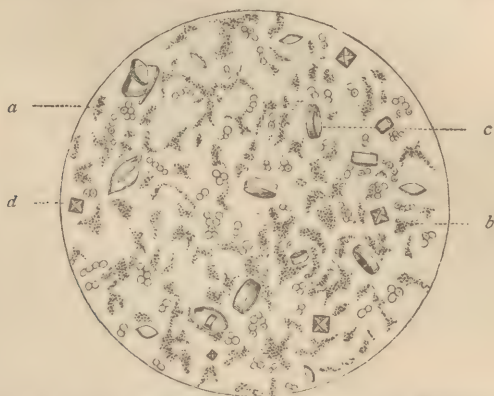
FIG. 76.—DEPOSIT IN "ACID FERMENTATION" OF URINE. (*a*) FUNGUS; (*b*) AMORPHOUS SODIUM URATE; (*c*) URIC ACID; (*d*) CALCIUM OXALATE.

holding the finger upon the upper end until it is depressed to the bottom of the glass, and then, on removing the finger for an instant, the sediment will be drawn up into the tube, when it may be removed for examination. It is more convenient, for the microscopical examination of urinary sediments, to **dispense with the usual cover-glass,** as a larger field is available for search for characteristic objects. To the **crystalline deposits** belong uric acid, urates, calcium oxalate, the phosphates or carbonates of magnesium and calcium, cystin, hippuric acid, leucin, tyrosin, etc. **Organized deposits** include mucous corpuscles, blood, pus, casts, epithelium, fungi, and bacteria.

The chemical examination of the deposits should be preceded by a microscopical examination. In fact, with a little experience, the microscopical examination may greatly assist in the chemical exam-

ination.   Most of the unorganized and crystalline sediments may be easily recognized by microscopical better than by chemical means.

Crystalline Deposits.—Uric acid occurs in crystals, differing much in form and size, and stained a brownish-yellow to a light lemon-yellow color by uroxanthin.   They are sometimes large, and when grouped together, as at *d*, figure 77, are large enough to be seen with the naked eye.   They dissolve when warmed with NaOH solution. The most characteristic forms are those shown in figures 76 and 77.

Acid Urates.—Amorphous urates consist principally of acid sodium urate. (See Fig. 76.) The deposit is amorphous unless a very high magnifying power is employed.   Then it is seen to be made up of minute globular particles of a yellow, red, or brown color.   This
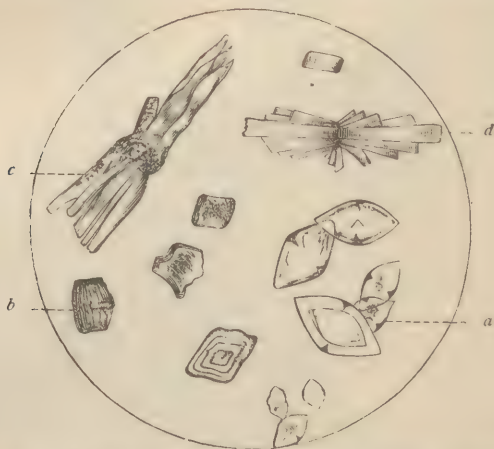
FIG. 77.—URIC ACID.   (*a*) RHOMBIC TABLES (WHETSTONE FORM) ; (*b*) BARREL FORM ; (*c*) SHEAVES ; (*d*) ROSETTES OF WHETSTONE CRYSTALS.

sediment separates only from acid urines.   It dissolves to a clear solution on adding a solution of NaOH or KOH, or when heated.

For the purpose of testing the solubility of the sediment under the microscope, it will be found convenient to place a drop or two of the solvent on the slide at one side of the cover-glass, and put on the other side a piece of bibulous paper.   In this way the fluid is drawn under the cover-glass on the one side and removed at the other, the old liquid being replaced by the new.   In this way the action of the reagent upon urinary sediments may be readily observed.

Acid sodium urate sometimes crystallizes during the acid fermentation, in the form of larger spheres made up of elongated crystals. They appear under the microscope as yellow or brown, frequently

almost opaque spheres, with one or more spicules. When the urine becomes alkaline from fermentation, the amorphous urates are gradually converted into ammonium urate, which has the appearance seen in figure 78.
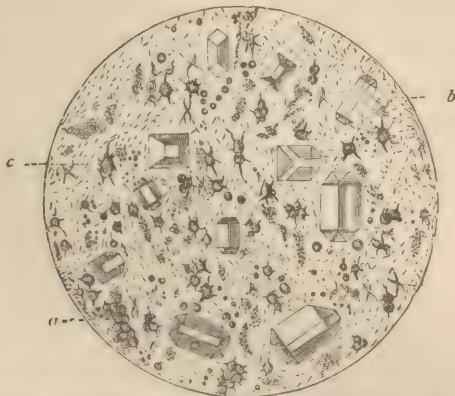
FIG. 78.—DEPOSIT OF AMMONIACAL URINE (ALKALINE FERMENTATION). (a) ACID AMMONIUM URATE; (b) AMMONIO-MAGNESIUM PHOSPHATE; (c) BACTERIA.

Calcium oxalate occurs as a sediment in transparent, strongly refracting, regular octahedrons, which are readily soluble in HCl, but insoluble in acetic acid. They frequently accompany uric acid crystals, and deposit during the acid fermentation, as shown in figure 76.
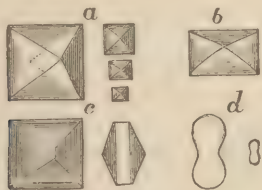
FIG. 79.—OXALATE OF LIME. (a) OCTAHEDRA; (b) BASAL PLANE OF AN OCTAHEDRON FORMING A RECTANGLE; (c) COMPOUND FORMS; (d) DUMB-BELLS.
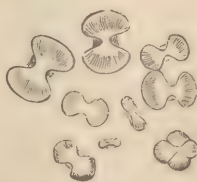
FIG. 80.—PERFECT DUMB-BELL CRYSTALS OF OXALATE OF LIME.

They are frequently called envelope-shaped crystals, from the fancied resemblance to the reverse side of an envelope. They are usually of very small size, and occasionally appear in the form of dumb-bells. (Figs. 79 and 80.) A few isolated crystals of calcium oxalate have

no clinical significance. They greatly increase after eating such vegetables as tomatoes, fresh beans, beet-root, asparagus, apples, grapes, honey, and after the administration of rhubarb, senna, squills, etc. Another source of oxalic acid in the body is incomplete oxidation of carbohydrates and proteid, retrograde, decomposition products. For this reason it is frequently met with in excess in diabetes mellitus. It is frequently excessive in fermentative disturbances in the intestinal canal, and in certain nervous disturbances. The long-continued excretion of an excess of oxalate of calcium frequently irritates the kidneys, producing albuminuria, and grave nervous disturbance, and may lead to the formation of calculi, espe-
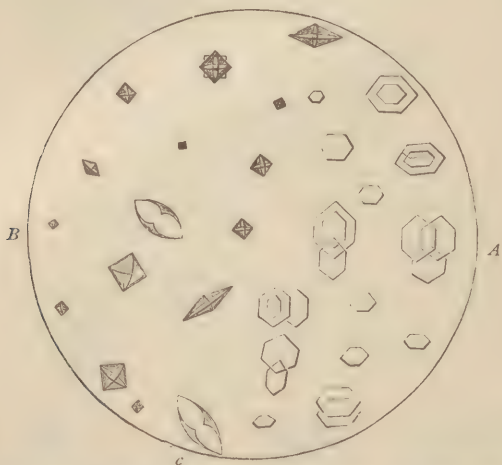
FIG. 81.—A, CRYSTALS OF CYSTIN; B, OXALATE OF LIME; (c) HOUR-GLASS FORMS OF B.

cially renal calculi. It is usually associated with an excessive amount of uric acid, mucus, and phosphates.

Ammonium-magnesium phosphate (triple phosphate) occurs as a sediment in neutral or in alkaline urine. The crystals are large, transparent, highly refracting prisms, usually in the form seen in figure 83. Occasionally it occurs in the form of feathery crystals, or star-shaped groups. They are never colored. They frequently attain a size sufficient to render them visible to the naked eye, especially in a strong light.

Magnesium phosphate is occasionally deposited in concentrated urines of feebly alkaline reaction.

Calcium phosphate crystals appear as pointed, wedge-shaped prisms, either singly or in clusters. They are dissolved by acetic or hydrochloric acid.
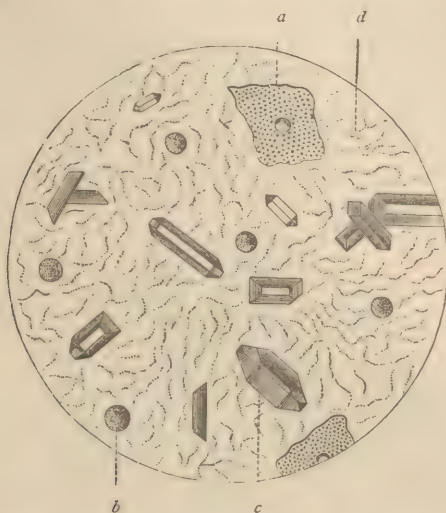
FIG. 82.—DEPOSIT FROM A CASE OF INFLAMED BLADDER (AMMONIACAL FERMENTATION). (*a*) DETACHED EPITHELIUM; (*b*) PUS-CORPUSCLES; (*c*) TRIPLE PHOSPHATE; (*d*) MICROCOCCUS UREÆ.
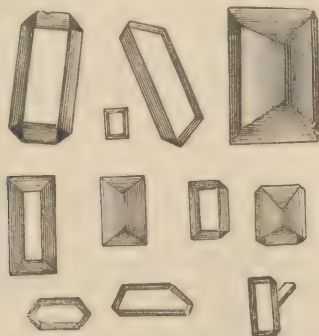
FIG. 83.—THE MORE USUAL FORMS OF TRIPLE PHOSPHATE. × 300.

Calcium sulphate is rarely present as a urinary sediment. It occurs in the form of long, colorless needles or prisms, or in elongated tables with abrupt extremities.

Calcium carbonate occasionally occurs in the urine as an amorphous deposit, but on higher magnification it is seen to be made up of minute spherical granules. (See Fig. 86.)

Hippuric acid occasionally occurs as a sediment in the urine in the form of four-sided prisms, either occurring separately or in groups. They are soluble in ammonia, insoluble in HCl. It occurs especially after the administration of benzoic acid and after eating certain fruits, as cranberries, bilberries, etc. It is of no diagnostic importance.

Cystin.—The crystals of this body appear as regular hexagonal plates, superimposed or contiguous to one another. (See Fig. 81.)

FIG. 84.—HIPPURIC ACID.

They are insoluble in acetic acid, but soluble in ammonia. It is sometimes also found in solution in the urine. Cystin is a decomposition product of proteid matter, and generally the result of bacterial action in the intestines. It is frequently associated with diamins and ethereal sulphates. It sometimes forms calculi.

Leucin and **tyrosin** always occur together. Tyrosin occurs in the sediment in the form of sheaves of very fine crystals. **Leucin,** commonly associated with tyrosin, is more soluble, but occurs to some extent in the sediment in the form of small spheres, not unlike oil globules, which in a good light are seen to be marked with radiating striæ. When quite pure, leucin crystallizes in delicate plates, but as

a urinary sediment it usually forms spheres. (See Fig. 85.) Tyrosin has been found in the urine, together with leucin, in phosphorus poisoning, in acute yellow atrophy of the liver, in leukemia, and in some of the infectious diseases.

Fat is deposited in the form of strongly refracting globules of varying size, and readily soluble in ether. It may be present in the urine in small quantities after the fracture of bones, and in some chronic cases of Bright's disease attended with fatty degeneration. In chyluria it occurs in greater abundance.

Indigo occasionally occurs as a sediment in concretions and amorphous fragments, and also in the form of blue crystals and clusters of
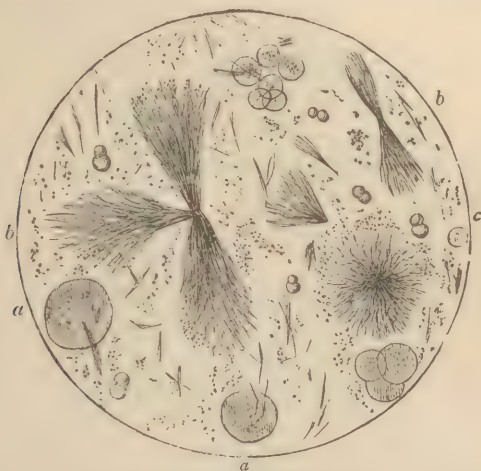
FIG. 85.—(*a a*) LEUCIN BALLS; (*b b*) TYROSIN SHEAVES; (*c*) DOUBLE BALLS OF AMMONIUM URATE.

fine, blue needles. The crystals of indigo are not rare in decomposing and fermenting urines, in which they result from the decomposition of the indoxyl-sulphate. They occur more especially in the urine of hepatic abscess and in cirrhosis of the liver.

Urinary concretions of considerable size are occasionally to be seen in urine with the naked eye. They consist, for the most part, of urates, or urates with uric acid. Their recognition is important in the diagnosis of renal colic. When composed of uric acid or acid urates, their color is usually red or brown. Phosphatic concretions of larger size occur more rarely. They are light-colored. Other concretions are occasionally met with.

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Foreign bodies occur in the urine from accidental causes, or from negligence in collecting the specimen. We may mention fungi, yeast-cells, micro-organisms, fat globules; fibers of silk, linen, and wool; feathers, wood, starch, etc. Bodies of this kind will be seen in almost every specimen examined. They will not cause any confusion, after a little practice, as they are so different from any of the characteristic urinary sediments that mistakes will rarely be made. Fragments of tumors, as sarcoma, carcinoma, etc., may occasionally be found, and their import is self-evident.

Organized Deposits.—Mucous corpuscles are seen as round, finely granular cells, somewhat larger than blood-corpuscles, and con-
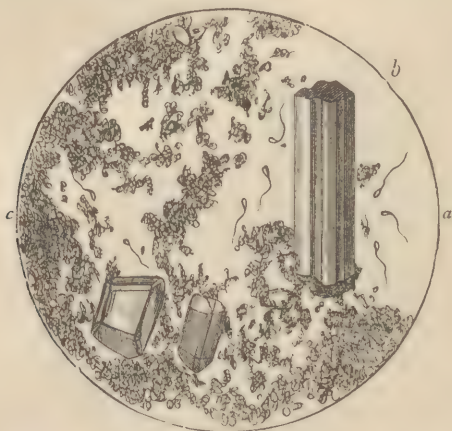
FIG. 86.—(a) SPERMATOZOA; (b) AMORPHOUS CALCIUM CARBONATE; (c) AMMONIUM MAGNESIUM PHOSPHATE.

taining from three to five nuclei. They can not be distinguished from the colorless blood-corpuscles. (See Fig. 90.) **Pus-corpuscles** resemble the mucous corpuscles in their appearance. If fresh, warm urine containing mucous or pus-corpuscles be examined under the microscope, the corpuscles will be seen to undergo the ameboid change of shape. When the urine becomes cold, this movement ceases, and the corpuscles assume the globular form. Water causes these corpuscles to swell, the nuclei becoming more distinct, and the outline gradually disappearing. Acetic acid produces a similar change, but more rapidly. Solutions of KOH, NaOH, and NH_4OH disintegrate these corpuscles, destroying the cells and granules; the nuclei
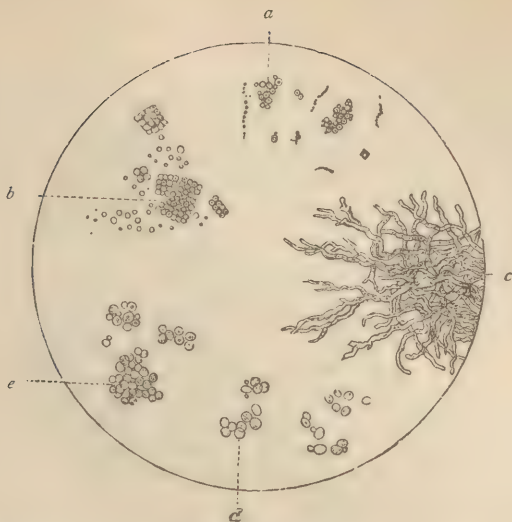
FIG. 87.—(a) MICROCOCCI IN SHORT CHAINS AND GROUPS; (b) SARCINÆ; (c) FUNGI FROM ACID FERMENTATION; (d) YEAST CELLS FROM DIABETIC URINE; (e) MYCELIUM OF A FUNGUS, OR MOLD.
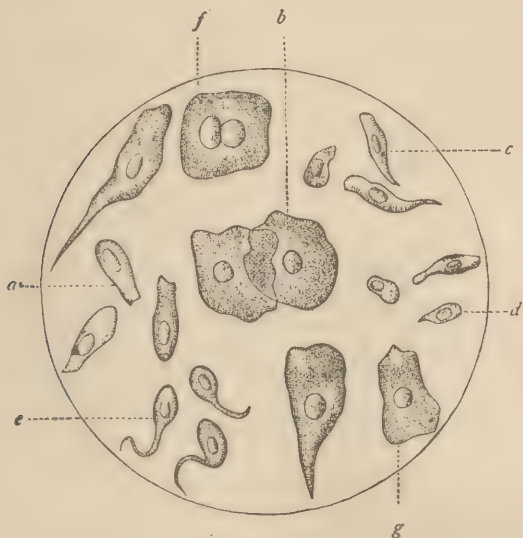
FIG. 88.—(a) EPITHELIAL CELLS FROM THE MALE URETHRA; (b) FROM THE VAGINA; (c) FROM THE PROSTATE; (d) COWPER'S GLANDS; (e) LITTRE'S GLANDS; (f) FEMALE URETHRA; (g) BLADDER.

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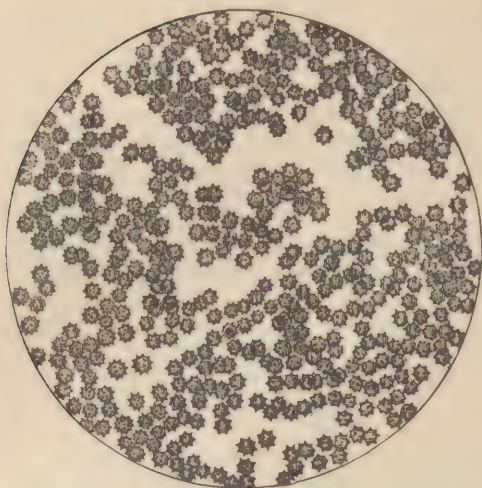
FIG. 89.—CRENATED RED BLOOD-CORPUSCLES IN THE URINE. × 350.
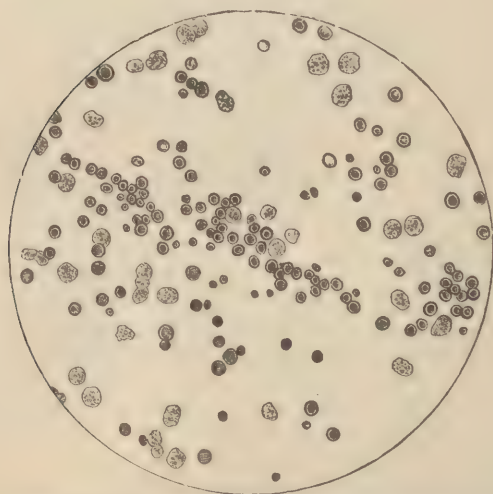
FIG. 90.—RED AND COLORLESS BLOOD-CORPUSCLES OF VARIOUS FORMS.

are the last to disappear. In alkaline urines, therefore, the mucous and pus-corpuscles, if present, rapidly undergo disintegration.

Epithelial cells of a variety of shapes are found in normal urine. Those from the convoluted portion of the tubules are polygonal in shape, but on remaining for some time in the urine they absorb water and become globular. They are a little larger than pus-corpuscles, and may be distinguished from the latter by having but one large, distinct nucleus. The epithelial cells of the loop of Henlé and the larger collecting tubes are columnar in shape. Those from the ureter, pelvis, and male urethra are elongated and conical, containing one nucleus near the center. Large, flat, squamous, epithelial cells are obtained from the bladder, vagina, and female urethra. (Fig. 88.) In chronic cystitis, after the large, flat, irregular cells have been shed off, we may have smaller, rounded cells. Rapidly proliferating cells have a large nucleus in proportion to the remainder of the cell. Old cells, slowly proliferated and desquamated, have a smaller nucleus in proportion to the rest of the cell. This is of importance in the diagnosis of new growths likely to be found in the bladder.

Blood-corpuscles in the urine appear as small, round, disc-shaped corpuscles of a light straw or red color, and when seen on edge appear biconcave. They are prone to changes in form and size on standing for some hours. They undergo decomposition in alkaline urines, change their form, and finally become invisible. (Figs. 89 and 90.)

Casts.—Casts are fibrinous molds of the uriniferous tubules, and frequently contain blood- or pus-corpuscles, epithelial cells, granular matter, crystals, or oil-drops, imbedded in the substance of which they are composed, from which they are named epithelial casts, blood-casts, granular casts, fatty casts, waxy casts, and hyaline casts.

Hyaline casts are perfectly clear, transparent cylinders, without markings. having nearly the same refractive index as the urine, and consequently are not readily seen, especially in a strong light. (Fig. 91.) They are more readily seen with oblique illumination, or by adding a few drops of solution of eosin, Bismarck brown, methyl-green, or fuchsin, to the urine while the sediment is forming. They are characteristic of the very earliest and the recovering stages of nephritis, and are also found in congestion of the kidney, or in simple irritative catarrh of the tubules.

Blood-casts contain blood-corpuscles imbedded in them, and indicate an acute inflammation of the kidney with escape of blood-corpuscles from the circulation into the tubules. (See Fig. 92.) They are characteristic of the very acute stages of nephritis.

Epithelial casts are those in whose surfaces epithelial cells from

the tubules are imbedded. (See Fig. 93.) They indicate a rapid shedding of the epithelial cells lining the tubules, and usually occur in the second stage of the inflammation—*i. e.*, when the inflammation has loosened the epithelial cells. They will usually be found only in acute nephritis.

Granular casts are those containing granules, either small or large. The granular matter may come from either the disintegration of the epithelial cells, blood-cells, or from the material of the cast itself. They are frequently spoken of as finely granular, moderately granular, and coarsely granular ; the amount of granular matter giving an idea of the amount of the destructive disintegration taking place

FIG. 91.—HYALINE CASTS.   FIG. 92.—BLOOD-CAST.

in the kidney. The dense, coarsely granular varieties, represented by figure 94, *b*, are more especially found in chronic cases. The finely granular cast seen in figure 94, *a*, may be found in the chronic or in the subacute form of the disease.

Fatty casts, or **oil casts**, are such as reveal oil drops in the cast material. They occur in chronic nephritis attended by fatty degeneration. It is sometimes difficult to determine whether the granular degeneration seen in these casts is due to the degeneration of the cast itself, after having been formed, or whether it is the result of the disintegration of blood-cells or epithelial cells. These casts form in the tubules, and often remain there for a considerable time—a sufficient

time, perhaps, to undergo granular and even fatty degeneration. It is certain that the coarsely granular and fatty casts are never found in the earlier stages of the disease.

Waxy casts are a variety somewhat resembling hyaline casts, but

FIG. 93.—EPITHELIAL CASTS.   FIG. 94.—GRANULAR CASTS.

are more dense and more distorted, and frequently are cracked or torn along the edges, or they have lost the regularity of their outline. They sometimes give a blue color with sulphuric acid and iodine, are more refractive than hyaline casts, and are insoluble in acetic acid, while hyaline casts are soluble.

Mucous casts are frequently spoken of. They are long, transparent, fibrillar bodies, twisted and branching, and lacking in the terminal features of casts. They should not be regarded as casts, although we may meet with mucous plugs from the follicles in the prostatic urethra which closely resemble casts. The character of the epithelial cells, with which they are associated, will usually serve to distinguish them. The absence of albumin will also assist. True renal casts

FIG. 95.   FIG. 96.

without albumin in solution are rare. Hyaline casts without albumin are not rare, but they are frequently mucous instead of true tube-casts.
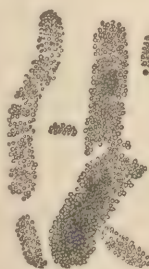
Casts can usually be readily distinguished from other bodies met

with in the urine by the peculiarly rounded end, formed by the pushing of the cast material through the tubule by pressure from behind, while still in a plastic condition. This rounded extremity is one of the most characteristic features in casts, and when in doubt as to the identity of an object, this will often serve as a guide.

Casts like formations of **urates** will occasionally be met with, and always resemble granular casts. (See Fig. 95.) Masses of micrococci closely resembling casts will also occasionally be seen, but these can usually be distinguished by their appearance, or by their resistance to reagents, as caustic potash, nitric acid, etc. **Leucocyte casts** (Fig. 96.) are met with in suppurating conditions of the tubules of the kidney, in gonorrhea, prostatitis, and leucorrhea.

Granular Detritus.—Under this name we will designate the ill-defined granular or disintegrating masses of material frequently met with in cases of nephritis. These irregular or amorphous masses are probably partially disintegrated cells or masses of free granules of this origin. The amount of this material in any specimen of nephritic urine should be noted, as an aid in arriving at a clear idea of the amount of destructive change going on in the kidney. This point is an important one in prognosis, as by it we are able to determine that organic destruction of the kidney is rapidly progressing and the prognosis unfavorable ; or, that there is little or no organic destruction and the prognosis better.

The following scheme for the chemical and microscopical examination of sediments will be found useful as a guide to rapid work :

URINARY DEPOSITS.

CHEMICAL EXAMINATION.

Draw off a portion of the sediment with a pipette or glass tube, and transfer to a watch-glass or small test-tube.

White Deposit.
- Dissolves on heating urine, ... *Ammonium urate.*
- Insoluble on heating.
  - Sol. in NH₄OH, ... *Cystin.*
  - Insol. in NH₄OH,
    - Soluble in acetic acid, *Earthy Phosphates.*
    - Insoluble in acetic acid, *Calcium oxalate* or *oxalurate.*
  - Gelatinizes in NH₄OH, *Pus* (see above).

Colored Deposit.
- Visibly crystalline (red), ... *Uric acid.*
- Amorphous,
  - Pale, easily soluble by heat, ... *Urates.*
  - Deep-colored, slowly soluble by heat, *Acid urates with uroerythrin.*
  - Red, insoluble by heat, alkalies, or acids, . . . *Blood.*

MICROSCOPICAL EXAMINATION.

With a clean pipette draw off a small portion of the sediment, transfer to a clean glass slide, and examine with a ½-in. or ¼-in. objective. A cover-glass may be dispensed with.

Deposit is Amorphous.
- Small granules with spicules on larger granules; vanishes on adding KOH or NaOH, ... { light = *Sodium urate.* dark = *Ammonium urate.*
- Permanent on adding KOH or NaOH, . . *Calcium carbonate* (rare).
- Globules, strongly refracting light, ... *Fat.*

Deposit is Crystalline.

Urine, Acid.
- Yellow, cross or whetstone shaped, or in groups, *Uric acid.*
- Regular octahedra, envelope-shaped, . . . *Calcium oxalate.*
- Hexagonal plates, soluble in NH₄OH (white), . . . *Cystin.*
- Bundles of needles crossing each other, ... *Tyrosin.*

Alkaline Urine.
- Large prisms, soluble in acetic acid (coffin-lid shaped), ... *Ammonium magnesium phosphate.*
- Brown, double spheres, spiculated, *Urate of ammonium.*
- Club-shaped crystals, single or in groups, *Calcium phosphate.*
- Double spheres, radiated structure, soluble in acetic acid, with effervescence, . . *Calcium carbonate* (rare).
- Double spheres, insoluble in acetic acid, *Calcium oxalurate* (rare).
- Double spheres, yellow or red, striated, . . *Uric acid.*

Cellular Elements.
- Red or yellow discs, biconcave; sometimes irregular in outline, *Blood-cells.*
- Granulated corpuscles. With diluted acetic acid, show 3 to 5 nuclei, { Albumin present, ... *Pus.* Albumin absent, *Mucous corpuscles.*
- Round, conical, or flat cells with one nucleus, *Epithelium from urinary tract.*
- Tadpole-shape, with long tail (small), ... *Spermatozoa.*
- Cylinders, parallel margins, clear, granular, or containing epithelial cells or blood-cells, ... *Casts of uriniferous tubules.*
- Fungi, yeast, hairs, threads, etc., etc., ... *Extraneous matters.*

URINARY CALCULI.

Urinary calculi, or concretions, are hard masses of urinary sediments formed in the kidney, ureters, bladder, or sinuses of the prostate gland. They are **simple**, composed of one kind of material, or **compound** or **mixed**, composed of two or more kinds of material, deposited in concentric layers. In the examination of a calculus it should be sawed through so as to expose these layers, and small portions of each layer examined separately. An examination of a calculus is necessary to determine the condition which led to its formation, and to suggest proper treatment to prevent the formation of others. About sixty per cent. of all urinary calculi are composed of uric acid or acid urates. They are generally reddish and smooth,

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but sometimes tuberculated. About forty per cent. of the remainder of the stones are mixed uric acid and earthy phosphates, containing rather more of the latter ingredients. When the calculus starts as a uric acid concretion, and the urine changes from acid to alkaline, the phosphates are deposited. This is apt to occur sooner or later. The cross-section of such a calculus shows very plainly the different layers.

Calcium oxalate calculi, or **mulberry calculi**, comprise about three per cent. of all cases operated upon. They are gray or dark brown, very hard, and generally tuberculated, when they are often called "mulberry calculi." When smooth they are often called "hempseed calculi."

The phosphatic calculi are rare, as are those composed of calcium carbonate, cystin, xanthin, fibrin, blood, indigo, and urostealith.

The following is a scheme for the qualitative examination of calculi :

These last, composed of calcium and magnesium soaps, fat, albumin, etc., are very rare.

Heat a portion of the powdered stone on a platinum-foil or charcoal with blowpipe.

A. *It chars and burns with a flame.* Probably xanthin, cystin, urostealith, or fibrin.

1. The flame burns briefly, emitting odor of SO_2. The powder dissolves in ammonia, and on diluting deposits six-sided plates = **Cystin**.

2. It does not give the murexid test. The powder is soluble in HNO_3, without effervescence, and the dried residue becomes orange with alkalies and red on warming = **Xanthin**.

3. The flame is yellow, prolonged, and gives the odor of burning shellac. The powder is soluble in alcohol = **Urostealith**.

4. The flame is yellow, prolonged, and gives the odor of burning feathers. Soluble in hot KOH solution, and is precipitated again by acetic acid = **Fibrin**.

B. *It chars, but does not burn with flame.*

1. The powder gives the murexid test.

a. It gives off NH_3 when warmed with KOH solution = **Urate of Ammonium.**

b. It gives no NH_3 with KOH = **Uric Acid.**

C. *The powder does not strongly char or burn.* Treated with diluted HCl.

1. It dissolves with effervesence = **Calcium Carbonate.**

2. It dissolves without effervescence, and the solution gives a white precipitate with NH_4OH = **Phosphates** or **Calcium Oxalate.**

Treat the powder with acetic acid.

Phosphates dissolve without effervescence.

Mixed phosphates fuse in heating on foil.

Calcium phosphate does not fuse.

Triple phosphate gives off NH_3 when warmed with a little KOH solution.

Calcium oxalate is insoluble in acetic acid. After ignition it gives an alkaline powder, which effervesces with acetic or diluted HCl.

The subjoined table gives the most prominent variations in physical and chemical characters, with brief notes of their significance. As there are numerous handbooks upon this subject, the student is referred to them for details:

THE URINE OF THE TWENTY-FOUR HOURS—NORMAL AND PATHOLOGICAL.

PHYSICAL CHARACTER.	NORMAL.	ALTERATIONS IN ABNORMAL CONDITIONS.
Color.	Pale straw to reddish yellow. The average color is amber.	Colorless: neuroses, chronic nephritis, diabetes. High-colored: acute fevers, icterus. Blood-red: blood or foreign color. Dark brown: hematuria, poisoning by carbolic acid, potass. chlorate, or iodoform. Smoky brown: presence of decomposed blood, acute nephritis. Yellow or green: presence of bile. White: chyle or pus.
Transparency.	Clear, with only a slight flocculent cloud of mucus.	Urine turbid when passed, is abnormal. Whitish sediment may be pus, phosphates, or ammonium urate.
Consistence.	When normal, urine is mobile, like water.	When viscid, it indicates albumin, bile, mucus, or pus.
Odor.	Peculiar to itself.	Urine putrid when passed, indicates cystitis.
Reaction.	Slightly acid; becomes more acid on standing, then becomes alkaline.	Urine strongly acid in fevers and inflammations of the liver, heart, and lungs; in acid dyspepsia. Urine is alkaline in cystitis, and occasionally in debility, chlorosis, certain organic nervous diseases, typhus, etc.

THE URINE OF THE TWENTY-FOUR HOURS—NORMAL AND PATHOLOGICAL.—*Continued*.

CONSTITUENTS.	AMOUNT IN GRAINS.	ALTERATIONS IN PATHOLOGICAL CONDITIONS.
Sulphuric acid.	23 to 38	Having more or less the same source as urea, it will increase or diminish therewith. Occurs as sulphuric ethers, and preformed.
Phosphoric acid.	46 to 54	Increased in fevers, in nerve-exhaustion, disease of spinal cord, and in tubercle of the lung. In phosphatic diabetes the alkaline phosphates are greatly increased. Diminished in many mental diseases, especially mania, and in chlorosis.
Oxalic acid.	0.3	Increased in catarrhal jaundice, and in oxalic acid diathesis, mental depression, and certain forms of dyspepsia.
Phosphate of lime.	4 to 5	Increased in osteomalacia, rickets, scrofula, carcinoma, long-continued suppuration, organic disease of the spinal cord. Diminished in fevers.
Phosphate of magnesium.	7 to 11	
Chloride of sodium.	150 to 200 Cl = 90 to 120 Na 60 to 80	Increased in fevers at the outset, and with the re-absorption of dropsical fluids. Diminished during apyrexia, dropsies, cholera, typhus, inflammations generally, and especially in the forming stage of pneumonia.
Free acid (calculated as oxalic acid).	30 to 60	Increased during the acme of acute febrile affections (on account, probably, of the diminished proportion of water present). Diminished in most diseases affecting the nutrition and leading to a deficiency thereof.
Total inorganic salts. Potassium. Sodium. Calcium. Magnesium.	200 to 380 38 to 48 140 to 180 4 to 5 2 to 3	

ORGANIC CONSTITUENTS.

Urea.	450 to 500 or 30 to 34 gm.	Increased after much meat, fevers, diabetes mellitus, copious drinking of water or alcohol, congestion of liver. Diminished in abstinence from meat, rest, hepatic abscess, nephritis, chronic wasting diseases.

THE URINE FOR THE TWENTY-FOUR HOURS—NORMAL AND PATHOLOGICAL.—*Continued*.

ORGANIC CONSTITUENTS.	AMOUNT IN GRAINS.	ALTERATIONS IN PATHOLOGICAL CONDITIONS.
Uric acid.	4 to 15 (ratio to urea, 1 : 40)	**Increased** leucocythemia, pernicious anemia, gout, rheumatism, deficient oxidation; organic diseases of heart, lungs, liver, or skin; after acute fevers and excessive meat diet. **Diminished** in vegetable diet, gout, before attack, chronic renal disease, outdoor exercise.
Hippuric acid.	5 to 15	**Increased** with vegetable diet, after taking benzoates. **Decreased** in animal diet.
Creatinin.	8 to 15	**Increased** in meat diet, and increased nitrogenous metabolism. **Decreased** in vegetable diet, and milk diet.
Xanthin Bases.	0.5 to 2	**Increased** in splenic disease, meat diet, deficient oxidation. **Decreased** in vegetable diet.
Carbolic acid, Cresol, etc.	0.015	**Increased** in certain diseases of the intestines, causing constipation (ileus, etc.), but has been observed to be increased also in certain cases of diarrhea.
Indoxyl.	0.07 to 0.05	**Increased** with diseases attended by constipation and intestinal fermentation, and occasionally, also, in cases of diarrhea. After cholera, cancer of the liver and stomach, purulent peritonitis. Valuable diagnostic sign in typhoid fever and cancer of the liver.
Acetone, Diacetic acid, Hydroxybutyric acid.	Traces. " "	**Increased** in diabetes mellitus; conditions of increased proteid metabolism, with deficient oxidation.
Albumin.	None.	Nephritis, pregnancy, poisoning by certain substances, cold baths, violent exercise, rheumatism, infectious fevers, etc.
Albumose.	None.	Presence not clearly diagnostic.
Peptone.	None.	" " " "
Dextrose.	None or trace.	Glycosuria and diabetes mellitus.
Lactose.	None.	During lactation, after weaning.
Bile.	None.	Obstruction in bile-duct, structural hepatic diseases, malaria, pernicious anemia, yellow atrophy of liver, typhoid fever, and AsH_3 poisoning.
Blood.	None.	Hemorrhages, giving hematuria; hemoglobin in malaria, acute nephritis (sometimes).
Pus.	None.	Suppuration.
Mucus.	Present.	**Increased** in any irritation along the urinary tract, by uric acid, calcium oxalate, etc., catarrh of bladder, urethra, vagina. Usually increased in acute fevers.

APPENDIX.

RULES FOR THE SPELLING AND PRONUNCIA-
TION OF CHEMICAL TERMS.

In 1887 a committee was appointed by the American Association
for the Advancement of Science to consider the question of attaining
uniformity in the spelling and pronunciation of chemical terms. The
work of this committee extended through the following four years.
As a result of wide-spread correspondence and detailed discussion at
the annual meetings of the Chemical Section of the American Asso-
ciation, the accompanying rules have been formulated and adopted by
the Association. They are submitted to chemists generally, and
especially to the large number of those engaged in teaching chemistry,
with the request that a cordial and earnest effort be made to render
their use general, and thus obviate the many difficulties arising from
the present diversities of style.

The following summary of the rules has been arranged in the form
of a chart, by the National Bureau of Education, for general distribu-
tion to high schools and colleges.

For the reasons stated in the preface, we have not adopted the
spelling here recommended for those substances that are official. We
have, however, adopted it in the names of the newer synthetic reme-
dies, and in organic compounds not used in medicine.

It is yet a matter of doubt whether these rules will be generally
adopted by English-speaking chemists. English chemists are not
generally favorably disposed toward the reforms proposed.

General Principles of Pronunciation.

1. The pronunciation is as much in accord with the analogy of the
English language as possible.

2. Derivatives retain as far as possible the accent and pronunciation of the root word.

3. Distinctly chemical compound words retain the accent and pronunciation of each portion.

4. Similarly sounding endings for dissimilar compounds are avoided (hence -id, -ite).

ACCENT.

In polysyllabic chemical words the accent is generally on the antepenult; in words where the vowel of the penult is followed by two consonants, and in all words ending in -ic, the accent is on the penult.

PREFIXES.

All prefixes in strictly chemical words are regarded as parts of compound words, and retain their own pronunciation unchanged (as ă'ceto-, ă'mĭdo-, ă'zo-, hȳ'dro-, ĭ'so-, nĭ'tro-, nitrō'so-).

ELEMENTS.

In words ending in -ium, the vowel of the antepenult is short if i (as iri'dium), or y (as dĭdȳ'mium), or if before two consonants (as că'lcium), but long otherwise (as tĭtā'nium, sĕlē'nium, chrō'mium).

alū'minum.	gold.	ruthē'nium.
a'ntimony.	hȳ'drogen.	samā'rium.
a'rsĕnic.	ĭ'ndium.	scă'ndium.
bă'rium.	ĭ'odin.	sĕlē'nium.
bi'smuth (biz).	iri'dium.	sĭ'licon.
bō'ron.	iron.	silver.
brō'mĭn.	lă'nthanum.	sō'dium.
că'dmium.	lead.	strŏ'ntium (shium).
că'lcium.	lĭ'thium.	sŭ'lfur.
ca'rbon.	magnē'sium (zhium).	tă'ntalum.
cē'rium.	ma'nganese (eze).	tellū'rium.
cē'sium.	me'rcury.	te'rbium.
chlō'rĭn.	mōlȳ'bdenum.	thă'llium.
chrō'mium.	nĭ'ckel.	thō'rium.
cō'balt.	nĭ'trogen.	tin.
colŭ'mbium.	ŏ'smium.	tĭtā'nium.
co'pper.	ŏ'xygen.	tŭ'ngsten.
dĭdȳ'mium.	palla'dium.	ūrā'nium.
e'rbium.	phŏs'phorus.	vănā'dium.
flŭ'orĭn.	plă'tinum.	ytte'rbium.
gă'llium.	potă'ssium.	ȳ'ttrium.
germā'nium.	rhō'dium.	zinc.
glŭ'cinum.	rubĭ'dium.	zircō'nium.

Also ămmō'nium, phosphō'nium, hă'logen, cȳă'nogen, ămĭ'dogen.

Note in the above list the spelling of the halogens, cesium, and sulfur ; f is used in the place of **ph** in all derivatives of sulfur (as sulfuric, sulfite, sulfo-, etc.).

TERMINATIONS IN -ic.

The vowel of the penult in polysyllables is short as (cȳă′nic, fūmă′-ric, arsĕ′nic, sĭlĭ′cic, ĭō′dic, būtȳ′ric), except (1) **u** when not used before two consonants (as mercū′ric, prū′ssic), and (2) when the penult ends in a vowel (as benzō′ic, olē′ic) ; in dissyllables it is long except before two consonants (as bō′ric, cĭ′tric). Exception : acē′tic or acĕ′tic.

The termination -ic is used for metals only where necessary to contrast with -ous (thus, avoid aluminic, ammonic, etc.).

TERMINATIONS IN -ous.

The accent follows the general rule (as plă′tinous, sŭ′lfurous, phŏ′sphorous, coba′ltus). Exception : acē′tous.

TERMINATIONS IN -ate AND -ite.

The accent follows the general rule (as ă′cetāte, vă′nadāte) ; in the following words the accent is thrown back : ă′bietāte, ă′lcoholāte, ă′cetonāte, ă′ntimonīte.

TERMINATIONS IN -id (FORMERLY -ide).

The final **e** is dropped in every case, and the syllable pronounced id (as chlo′rid, i′odĭd, hȳ′drĭd, ŏ′xĭd, hȳdrŏ′xĭd, sŭ′lfĭd, ă′mĭd, ă′nilĭd, mūrĕ′xĭd.

TERMINATIONS IN -ane, -ene, -ine, AND -one.

The vowel of these syllables is invariably long (as mē′thāne, ĕ′thāne, na′phthalēne, a′nthracēne, prō′pīne, qui′nōne, ā′cetone, kē′tōne).

A few dissyllables have no distinct accent (as benzēne, xȳlēne, cētēne).

The termination -ine is used only in the case of doubly unsaturated hydrocarbons, according to Hofmann's groupings (as propīne).

Terminations in -in.

In names of chemical elements and compounds of this class, which include all those formerly ending in -ine (except doubly unsaturated hydrocarbons), the final e is dropped, and the syllable pronounced ĭn (as chlō′rĭn, brō′mĭn, etc., ä′mĭn, ă′nilĭn, mo′rphĭn, quī′nĭn (kwī′-nĭn), vani′llĭn, alloxă′nthĭn, absi′nthĭn, emŭ′lsĭn, că′ffeĭn, cō′caĭn.

Terminations in -ol.

This termination, in the case of specific chemical compounds, is used *exclusively* for alcohols, and when so used is never followed by a final e. The last syllable is pronounced -ōl (as glȳ′cōl, phē′nōl, crē′sol, thȳ′mol (ti), glȳ′cerol, quī′nōl. Exceptions: älcohŏl, a′rgŏl.

Terminations in -ole.

This termination is always pronounced -ōle, and its use is limited to compounds which are not alcohols (as ĭ′ndōle).

Terminations in -yl.

No final e is used; the syllable is pronounced ўl (as ä′cetўl, ă′mўl, cē′rotўl, cē′tўl, ĕ′thўl).

Terminations in -yde.

The y is long (as ă′ldehȳde).

Terminations in -meter.

The accent follows the general rule (as hydrŏ′meter, barŏ′meter, lactŏ′meter). Exceptions: Words of this class used in the metric system are regarded as compound words, and each portion retains its own accent (as cē′ntime″ter, mi′llime″ter, kĭ′lome″ter).

Miscellaneous Words

which do not fall under the preceding rules.

Note the spelling: Albumen, albuminous, albuminiferous, asbestos, gramme, radical.

Note the pronunciation: A′lkalīne, a′lloy (n. and v.), a′llotropy, a′llotropism, ĭ′somerism, pŏ′lymerism, appară′tus (sing. and plu.), ä′qua regia, barȳ′ta, cĕntigrade, co′ncentrated, crystallĭn or crystal-līne, electrŏ′lysis, līter, mŏ′lecule, mŏlĕ′cular, nō′menclā″ture, olē′-fiant, vä′lence, ū′nivä″lent, bī′va″lent, trī′vä″lent, qua′drivä″lent, tĭ′trate.

A List of Words Whose Use Should be Avoided in Favor of the Accompanying Synonyms.

For—	Use—
sodic, calcic, zincic, nickelic, etc.,	sodium, calcium, zinc, nickel, etc.
chlorid, etc.,	chlorid, etc. (*vid.* termination in -ic, *supra*).
arsenetted hydrogen,	arsin.
antimonetted hydrogen,	stibin.
phosphoretted hydrogen,	phosphin.
sulfuretted hydrogen,	hydrogen sulfid, etc.
beryllium,	glucinum.
niobium,	columbium.
glycerin,	glycerol.
hydroquinone (and hydrochinon),	quinol.
pyrocatechin,	catechol.
resorcin, etc.,	resorcinol, etc.
mannite,	mannitol.
dulcite, etc.,	dulcitol, etc.
benzol,	benzene.
toluol, etc.,	toluene, etc.
thein,	caffein.
furfurol,	furfuraldehyde.
fucusol,	fucusaldehyde.
anisol,	methyl-phenate.
phenetol,	ethyl-phenate.
anethol,	methyl-allyl-phenol.
alkylogens,	alkyl-haloids.
titer (n),	strength or standard.
titer (v),	titrate.
monovalent,	univalent.
divalent,	bivalent, etc.
quantivalence,	valence.

Fate, făt, fär, mēte, mĕt, pīne, pĭn, marine, nōte, nŏt, mōve, tūbe, tŭb, rüle.

$$m\breve{y} = \mathrm{I}.$$

′ Primary accent; ″ secondary accent. N. B.—The accent follows the vowel of the syllable upon which the stress falls, but does not indicate the division of the word into syllables.

TABLE OF WEIGHTS AND MEASURES.

ENGLISH WEIGHTS.

TROY WEIGHT OR APOTHECARIES' WEIGHT (U. S. P.).

℔ Pound.	ʒ Ounces.	ʒ Drachms.	϶ Scruples.	gr. Grains.		gm. Grams.
1 . . . . 12 . . . . 96 . . . . 288 5760					=	373.2419
1 . . . . 8 . . . . 24 480					=	31.1035
1 . . . . 3 60					=	3.8879
1 20					=	1.2959
1					=	0.0648

AVOIRDUPOIS WEIGHT.

Pound.	Ounces.	Drachms.	Grains.		Grams.
1 . . . . 16 . . . . 256 . . . . 7000.				=	453.5926
1 . . . . 16 . . . . 437.5				=	28.3495
1 . . . . 27.343				=	1.7718

APOTHECARIES' OR WINE MEASURE (U. S. P.).

C. Gallon.	O. Pints.	f ʒ Fl. Ozs.	f ʒ Fl. Drachms.	♏ Minims.		c.c.
1 . . . . 8 . . . . 128 . . . . . . 1024 61440					=	3785.
0.1 . . . . . . 16 . . . . 128 7680					=	473.
1 . . . . 8 480					=	29.57
1 60					=	3.70
1					=	0.06

IMPERIAL MEASURE.
Adopted by the British Pharmacopœia.

Gallon.	Pints.	Fl. Ozs.	Fl. Drachms.	Minims.		c.c.
1 . . . . 8 . . . . 160 . . . . . . 1280 76800					=	4543.5
1 . . . . 20 . . . . . . 160 9600					=	567.9
1 . . . . 8 480					=	28.4
1 60					=	3.55
1					=	0.06

METRIC MEASURES.

MEASURES OF LENGTH.

1	Millimeter	=	0.001 of a meter.		
1	Centimeter	=	0.010 of a meter.		
1	Decimeter	=	0.100 of a meter	=	about 4 inches.
1	**Meter**	=	**1.000 Meter**	=	39.37 inches.
1	Decameter	=	10.000 meters.		
1	Hectometer	=	100.000 meters.		
1	Kilometer	=	1000.000 meters	=	about ⅝ of a mile.
1	Myriameter	=	10,000.000 meters	=	about 6⅓ miles.

MEASURES OF SURFACE.

1	Centaire	=	1 square meter	=	about 1⅕ square yards.
1	Are	=	100 square meters.		
1	Hectare	=	10,000 square meters	=	about 2½ acres.

MEASURES OF VOLUME.

1	Cubic centimeter	=	0.001 of a liter.
1	Liter (cubic decimeter)	=	1000 cubic centimeters.
1	Cubic meter	=	1000 cubic decimeters.
1	Cubic meter	=	1000 liters, or 1 kiloliter.
1	Cubic meter	=	1 stere.

MEASURES OF WEIGHT.

1	Milligram	=	0.001 of a gram	=	about $\frac{1}{64}$ of a grain.
1	Centigram	=	0.010 of a gram.		
1	Decigram	=	0.100 of a gram.		
1	**Gram**	=	**1.000 Gram**	=	about 15½ grains.
1	Decagram	=	10.000 grams.		
1	Hectogram	=	100.000 grams.		
1	Kilo(gram)	=	1000.000 grams	=	about 2⅕ pounds.
1	Tonneau	—	1000.000 kilos	=	about 1 ton.

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TABLES FOR THE CONVERSION OF WEIGHTS AND MEASURES.

Based upon the value 39.37 inches for the meter and 15432.2 grains for the kilogram.

The following tables embrace the chief measures of length, weight, and capacity, giving the required equivalents of the nine units. Multiple numbers are found by moving the decimal point to the right, and fractions by moving it to the left. Thus, if it be desired to find the equivalent of 125 grains in milligrams, we proceed as follows: By the table—

```
I gr.  =  64.80 mgm.,  and 100 grs. then = 6480 mgm.
2 grs. = 129.6    "      "    20 "    "   = 1296  "
5 grs. = 324      "      "     5 "    "   =  324  "
                              ___            ___
                              125 grains.    8100 milligrams.
```

As 1000 mgm. = 1 gm., the above would be 8.100 gm.

If it be desired to find the value of 1.45 gm. in grains, we proceed as follows:

```
I gm. =                         15.43  grains.
4 gm. = 61.72 grains 0.4  gm. =  6.172   "
5 gm. = 77.15   "    0.05  "  =  0.7715  "
                                _____
                                22.3735 grains.
```

GRAINS.	MGM.	INCHES.	MILLI-METERS.	FL. OZ.	C.C.	C.C.	MINIMS.
1 =	64.8	1 =	25.4	1 =	29.57	1 =	16.2
2 =	129.6	2 =	50.8	2 =	59.1	2 =	32.4
3 =	194.4	3 =	76.2	3 =	88.7	3 =	48.6
4 =	259.2	4 =	101.6	4 =	118.3	4 =	64.8
5 =	324.0	5 =	127.0	5 =	147.8	5 =	81.0
6 =	388.8	6 =	152.4	6 =	177.4	6 =	97.2
7 =	453.6	7 =	177.8	7 =	207.0	7 =	113.4
8 =	518.4	8 =	193.2	8 =	236.5	8 =	129.6
9 =	583.2	9 =	228.6	9 =	266.1	9 =	145.8

TROY OZ.	GM.	FEET.	METERS.	PINTS.	LITERS.	C.C.	FL. DRACHMS.
1 =	31.1	1 =	0.3048	1 =	0.473	1 =	0.27
2 =	62.2	2 =	0.6096	2 =	0.946	2 =	0.54
3 =	93.3	3 =	0.9144	3 =	1.419	3 =	0.81
4 =	124.4	4 =	1.2192	4 =	1.892	4 =	1.08
5 =	155.5	5 =	1.5240	5 =	2.365	5 =	1.35
6 =	186.6	6 =	1.8288	6 =	2.838	6 =	1.62
7 =	217.7	7 =	2.1336	7 =	2.311	7 =	1.89
8 =	248.8	8 =	2.4384	8 =	3.784	8 =	2.16
9 =	279.9	9 =	2.7432	9 =	4.257	9 =	2.43

Av. Oz.	Gm.	Minims.	c.c.	Gm.	Grains.	Liters.	Fl. Oz.
1 =	28.35	1 =	0.0616	1 =	15.43	1 =	33.8
2 =	56.70	2 =	0.1232	2 =	30.86	2 =	67.6
3 =	85.05	3 =	0.1848	3 =	46.29	3 =	101.4
4 =	113.40	4 =	0.2464	4 =	61.72	4 =	135.2
5 =	141.75	5 =	0.3080	5 =	77.15	5 =	169.0
6 =	170.10	6 =	0.3696	6 =	92.58	6 =	202.8
7 =	198.45	7 =	0.4312	7 =	108.01	7 =	236.6
8 =	226.80	8 =	0.4928	8 =	123.44	8 =	270.4
9 =	255.15	9 =	0.5544	9 =	138.87	9 =	304.2

Av. Pounds.	Kilo-grams.	Fl. Drachms.	c.c.	Kilos.	Av. Oz.	Liters.	Cu. Inches.
1 =	0.4536	1 =	3.7	1 =	2.2	1 =	61
2 =	0.9072	2 =	7.4	2 =	4.4	2 =	122
3 =	1.3608	3 =	11.1	3 =	6.6	3 =	183
4 =	1.8144	4 =	14.8	4 =	8.8	4 =	244
5 =	2.2680	5 =	18.5	5 =	11.0	5 =	305
6 =	2.7216	6 =	22.2	6 =	13.2	6 =	366
7 =	3.1752	7 =	25.9	7 =	15.4	7 =	427
8 =	3.6228	8 =	29.6	8 =	17.6	8 =	488
9 =	4.0824	9 =	33.3	9 =	19.8	9 =	549

Grs. per f$\mathrecht{3}$j $\times$ 0.2191 = grams per 100 c.c., or per cent.

ALPHABETICAL TABLE OF EQUIVALENT MEASURES.

1 Are . . . . = 100 sq. meters = 119.6 sq. yards.
1 Barrel (wine) . . . . = 1.192 hectoliters.
1 Barrel (imperial) . . . . = 1.635 hectoliters.
1 Bushel (dry) . . . . = 35.243 liters.
1 Centimeter . . . . = $\frac{1}{100}$ meter = 0.3937 in.
1 Cubic centimeter . . . . = 16.2 minims = 0.06102 cu. in.
1 Cubic centimeter of dist. water at 4° C. . . . . weighs 1 gram.
1 Cubic decimeter (1 liter) (1000 c c.) of dist. water . . . . weighs 1 kilogram.
1 Cubic decimeter (imperial measure) . . . . = 61.03 cu. in. = 0 8804 qt.
1 Cubic decimeter (American wine measure) . . 33.8 fluidounces, or 1.056 qts.
1 Cubic foot . . . . = 1628 cu. in. = 28,315.31 c.c.
1 Cubic foot of water at 62° F. (16.6° C.) . . . . weighs 62.32 lbs. av.
1 Cubic inch . . . . = 266 minims = 16.386 c.c.
1 Cubic inch of water at 62° F. (16.6° C.) . . weighs 252.46 grs. 16.372 grams.
1 Cubic meter (1 stere) . . . . = 1000 liters = 35.30 cu. ft.
1 Drachm (troy) . . . . = 3.888 grams = 60 grains.
1 Fluidrachm . . . . = 60 minims = 3.697 c.c.
1 Fluidounce (imperial) . . . . = 28 4 c.c. = 1.7329 cu. in.
1 Fluidounce (wine measure) . . . . = 29.57 c.c. = 1.8047 cu. in.
1 Fluidounce of water (wine measure) at 62° F. . . . . . weighs 456 grains.
1 Fluidounce of water (wine measure) at 60° F. . . . . weighs 29.57 grams.
1 Fluidounce of water (imperial) at 62° F. . . . . weighs 437.5 grains.
1 Foot (12 inches) . . . . = 34.48 centimeters.
1 Gallon (imperial) . . . . = 277.27 cu. in. = 4.543 liters.
1 Gallon (wine) . . . . = 231 cu. in. = 3.785 liters.
1 Gallon of water (imperial) . . . . . . weighs 10 lbs.; wine, gallon, 8.34 lbs.
1 Grain (troy) . . . . = 0.0648 gram.
1 Gram (weight of 1 c.c. of water at 4° C., 39.2° F.) . . . . = 15.4323 grains.
1 Inch . . . . = 2.54 centimeters.
1 Kilogram . . . . = 1000 grams = 2.7 lbs. troy 2 2046 lbs. av.
1 Liter (see cubic decimeter) . . . . = 61.027 cu. in.
1 Meter (one forty-millionth of earth's meridian) . . . . = 39.3708 in.
1 Minim . . . . = 0.0616 c.c. 1 minim of water weighs 0.95 grain.
1 Ounce (troy) . . . . = 480 grains = 31.1 grams.
1 Ounce (avoirdupois) . . . . = 437.5 grains = 28.35 grams
1 Pint (imperial) . . . . = 20 fluidounces = 567.93 c.c.
1 Pint (wine measure) . . . . = 16 fluidounces = 473.15 c.c.
1 Pound (troy) . . . . = 5760 grains = 373.24 grams.
1 Pound (avoirdupois) . . . . = 7000 grains = 453.59 grams.
1 Quart (imperial), 40 fluidounces . . . . . . = 69.97 cu. in. = 1.1358 liters.
1 Quart (wine measure), 32 fluidounces . . . . = 58.30 cu. in. = 0.9463 liter.
1 Ton (avoirdupois) . . . = 2000 lbs. 29,167 ounces troy 907.20 kilograms.
1 Tonneau . . . . = 1,000,000 grams = 1000 kilos = 2204.6 lbs. av.

TABLE OF SPECIFIC GRAVITIES NAMED IN THE U. S. PHARMACOPŒIA, 1890.

Compiled by Dr. J. F. Golding.

AT 15° C.

Aciduan aceticum, ... about 1.048
" " dilutum, . . . about 1.008
" " glaciale,
not higher than 1.058
" hydrobromicum dilutum,about 1.077
" hydrochloricum, ... about 1.163
" " dilutum, about 1.050
" hypophosphorosum dilutum,
about 1.046
" lacticum, ... about 1.213
" nitricum, ... about 1.414
" " dilutum, . . . about 1.057
" oleicum, ... about 0.900
" phosphoricum, . . . not below 1.710
" " dilutum, about 1.057
" sulphuricum, . . . not below 1.835
" " aromaticum,
about 0.939
" " dilutum, about 1.070
" sulphurosum, . . not less than 1.035
Adeps, ... about 0.932
Æther, Ether,* . . . . . 0.725 to 0.728
" " aceticus, . . . 0.893 to 0.895
Alcohol,† . . . . about 0.820
" absolutum,‡ . not higher than 0.797
" deodoratum,§ . . . . . about 0.816
" dilutum,‖ . . . . about 0.937
Amyl nitris, ... 0.870 to 0.880
Aqua ammoniæ, ... 0.960
" " fortier, ... 0.901
" hydrogenii dioxidi, about 1.006 to 1.012
Balsamum peruvianum, . . . 1.135 to 1.150
Benzinum, ... 0.670 to 0.675
Bromum, ... 2.990
Camphora, ... 0.995
Carbonei disulphidum, . . . 1.268 to 1.269
Cera alba, ... 0.965 to 0.975
" flava, ... 0.955 to 0.967
Cetaceum, ... about 0.945
Chloroform,¶ . . . . not below 1.490
Copaiba, ... 0.940 to 0.990
Creosotum, ... not below 1.070
Eucalyptol, ... 0.930
Fel bovis, ... 1.018 to 1.028
Glycerinum, ... not less than 1.250
Hydrargyrum, ... 13.5584
Iodoformum, ... 2.000
Iodum, ... **
Limonis succus, . . . not less than 1.030
Liquor ferri acetatis, . . . about 1.160
" " chloridi, ... about 1.387
" " citratis, ... about 1.250
" " nitratis, ... about 1.050
" " subsulphatis, . . . about 1.550
" " tersulphatis, . . . about 1.320
" hydrargyri nitratis, . . about 2.100

AT 15° C.

Liquor plumbi subacetatis, . . about 1.195
" potassæ, ... about 1.036
" sodæ, ... about 1.059
" " chloratæ, . . about 1.052
" sodii silicatis, . . 1.300 to 1.400
" zinci chloridi, . . . about 1.535
Mel, ... 1.375
Methyl-salicylas, ... 1.183 to 1.185
Oleum adipis, ... 0.910 to 0.920
" Æthereum, ... 0.910
" amygdalæ amaræ, . . . 1.060 to 1.070
" " expressum, . 0.915 to 0.920
" anisi, ... ††
" aurantii corticis, ... about 0.850
" " florum, . . 0.875 to 0.890
" bergamottæ, ... 0.880 to 0.885
" cadinum, ... about 0.990
" cajuputi, ... 0.922 to 0.929
" cari, ... 0.910 to 0.920
" caryophylli, ... 1.060 to 1.067
" chenopodii, ... about 0.970
" cinnamomi, ... 1.055 to 1.065
" copaibæ, ... 0.890 to 0.910
" coriandri, ... 0.870 to 0.885
" cubebæ, ... about 0.920
" erigerontis, ... about 0.850
" eucalypti, ... 0.915 to 0 925
" fœniculi, ... not less than 0.960
" gaultheriæ, ... 1.175 to 1.185
" gossypii seminis, . . . 9.920 to 0.930
" hedeomæ, ... 0.930 to 0.940
" juniperi, ... 0.850 to 0.890
" lavandulæ florum, . . 0.885 to 0.897
" limonis, ... 0.858 to 0.859
" lini, ... 0.930 to 0.940
" menthæ piperitæ, . . 0.900 to 0.920
" " viridis, . . . 0.930 to 0.940
" morrhuæ, ... 0.920 to 0.925
" myrciæ, ... 0.975 to 0.990
" myristicæ, ... 0.870 to 0.900
" olivæ, ... 0.915 to 0.918
" picis liquidæ, ... about 0.970
" pimentæ, ... 1.045 to 1.055
" ricini, ... 0.950 to 0.970
" rosæ, ... ††
" rosmarini, ... 0.895 to 0.915
" sabinæ, ... 0.910 to 0.940
" santali, ... 0.970 to 0.978
" sassafras, ... 1.070 to 1.090
" sesami, ... 0.919 to 0.923
" sinapis volatile, . . . 1.018 to 1.029
" terebinthinæ, . . . 0.855 to 0.870
" " rectificatum,
0.855 to 0.865
" theobromatis, ... 0.970 to 0.980
" thymi, ... 0.900 to 0.930

* 0.714 to 0.717 at 25° C.
† 0.812 at 25° C.
‡ 0.789 at 25° C.
§ 0.808 at 25° C.
‖ About 0.937 at 15° C. ; about 0.936 at 15.6° C.,
and about 0.930 at 25° C.

¶ 1.473 at 25° C.
** 4.948 at 17° C.
†† About 0.980 to 0.990 at 17° C.
‡‡ 0.865 to 0.880 at 20° C.

TABLE OF SPECIFIC GRAVITIES.—*Continued*.

AT 15° C.

Oleum tiglii, ... 0.940 to 0.960
Petrolatum liquidum, . . about 0.875 to 0.945
"　　　molle, ...　　*
"　　　spissum, ...　　†
Phosphorus, . . . 　 . . . . . .　　‡
Resina, ... 1.070 to 1.080
Spiritus ætheris nitrosi, ... about 0.82
"　　　ammoniæ, ... about 0.810
"　　　"　　aromaticus, . about 0 905
"　　　frumenti, . . . not more than 0.930
　　　　　　　　　nor less than 0.917
"　　　glonoini, ... 0.826 to 0.832

AT 15° C.

Spiritus vini gallici, . . not more than 0.941
　　　　　　　　　　nor less than 0.925
Syrupus, ... about 1.317
"　　acidi hydriodici, ... about 1.313
"　　ferri iodidi, ... about 1.353
Terebenum, ... about 0.862
Thymol, . . { solid—1.069
　　　　　　　{ liquefied—lighter than water
Tinctura ferri chloridi, ... about 0.960
Vinum album, ... §
"　　rubrum, ... ‖
Zincum, ... 6.9 (cast) to 7.2 (rolled)

TABLE SHOWING THE SOLUBILITY OF SOME CHEMICALS IN GLYCERIN. ONE
HUNDRED PARTS OF GLYCERIN DISSOLVE THE ANNEXED QUANTITIES OF
THE SALTS.—(*Klever*.)

	PARTS.		PARTS.
Arsenous Oxide, ...	20.00	Morphine Acetate, ...	20.00
Arsenic Oxide, ...	20.00	"　　Hydrochlorate, ...	20.00
Acid, Benzoic, ...	10.00	Phosphorus, ...	0.20
"　Oxalic, ...	15.00	Plumbic Acetate, ...	20.00
"　Tannic, ...	50.00	Potassium Arsenate, ...	50.00
Alum, ...	40.00	"　　Chlorate, ...	3.50
Ammonium Carbonate, ...	20.00	"　　Bromide, ...	25.00
"　　Chloride, ...	20.00	"　　Cyanide, ...	32.00
Antimony and Potassium Tar-		"　　Iodide, ...	40.00
trate, ...	5.50	Quinine, ...	0.50
Atropine, ...	3.00	"　　Tannate, ...	0.25
"　　Sulphate, ...	33.00	Sodium Arsenate, ...	50.00
Barium Chloride, ...	10.00	"　　Bicarbonate, ...	8.00
Brucine, ...	2.25	"　　Borate, ...	60.00
Cinchonine, ...	0.50	"　　Carbonate, ...	98.00
"　　Sulphate, ...	6.70	"　　Chlorate, ...	20.00
Copper Acetate, ...	10.00	Sulphur, ...	0.10
"　　Sulphate, ...	30.00	Strychnine, ...	0.25
Iron and Potassium Tartrate, . .	8.00	"　　Nitrate, ...	4.00
"　Lactate, ...	16.00	"　　Sulphate, ...	22.50
"　Sulphate, ...	25.00	Urea, ...	50.00
Mercuric Chloride	7.50	Veratrine, ...	1.00
Mercurous Chloride, ...	27.00	Zinc Chloride, ...	50.00
Iodine, ...	1.90	"　Iodide, ...	40 00
Morphine, ...	0.45	"　Sulphate, ...	35.00

* About 0.820 to 0.840 at 60° C.
† About 0.820 to 0.850 at 60° C.
‡ 1.830 at 10° C.

§ Not less than 0.990, nor more than 1.010, at
　15.6° C.
‖ Not less than 0.989, nor more than 1.010, at
　15.6° C.

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.

Explanation of Signs.—*s.* = soluble; *ins.* = insoluble; *sp.* = sparingly soluble; *v. s.* = very soluble; *alm.* = almost; *dec.* = decomposed.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f₃j.	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f₃j.
One part is soluble in—	Parts.		Parts.	
Acetanilid, ...	200	2.28	10	37.4
Acid, Arsenous, ...	30–80	15.2–57	sp.	. . .
" Benzoic, ...	500	0.9	3	124.6
" Boric, ...	25	18.2	15	24.9
" Carbolic, ...	20	22.8	v. s.	. . .
" Chromic, ...	v. s.	. . .	dec.	. . .
" Citric, ...	0.75	608	1	374
" Gallic, ...	100	4.5	4.5	83.1
" Salicylic, ...	450	1.01	2.5	149.6
" Tannic, ...	6	76	0.6	623
" Tartaric, ...	0.7	651	2.5	149.6
Agathin, ...	ins.	. . .	s.	. . .
Alphol, ...	ins.	. . .	s.	. . .
Alum, ...	10.5	43.4	ins.	. . .
" Dry (Exsiccatum), ...	20	22.8	ins.	. . .
Aluminum Hydroxide, ...	ins.	. . .	ins.	. . .
" Sulphate, ...	1.2	380	alm. ins.	. . .
Alumnol, ...	s.	. . .	sp.	. . .
Ammonium Benzoate, ...	5	91.2	28	13.3
" Bromide, ...	1.5	304	150	2.4
" Carbonate, ...	4	114	dec.	. . .
" Chloride, ...	3	152	1.37	273
" Iodide, ...	1	456	9	41.5
" Nitrate, ...	0.5	912	20	18.7
" Phosphate, ...	4	114	0.5	748
" Sulphate, ...	1.3	350.7	sp.	. . .
" Valerianate, ...	v. s.	. . .	v. s.	. . .
Amylene Hydrate, ...	ins.	. . .	5	75
Analgene, ...	ins.	. . .	sp.	. . .
Anthrarobin, ...	ins.	. . .	5	91.2
Antimony and Potassium Tartrate, . .	17	26.8	ins.	. . .
" Oxide, ...	alm. ins.	. . .	ins.	. . .
" Sulphide, ...	ins.	. . .	ins.	. . .
Antipyrin, ...	1	456	1	374
" Benzoate, ...	s. s.	. . .	sol.	. . .
Antispasmin, ...	s.	. . .	ins.	. . .
Apomorphine Hydrochlorate, ...	6.8	67	50	7.4
Apyonin, ...	s. s.	. . .	sol.	. . .
Aristol, ...	ins.	. . .	s. s.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.—*Continued*.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f3j.	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f3j.
One part is soluble in—	Parts.		Parts.	
Arsenic Iodide, ...	3.5	130.2	10	37.4
Asaprol, ...	1½	304	3	152
Atropine, ...	600	0.7	v. s.	. . .
" Sulphate, ...	0.4	1140	6.5	57.5
Benzanilid, ...	ins.	. . .	60	6.2
Benzonaphthol, ...	ins.	. . .	sol.	. . .
Benzophenoneid, ...	100	4.6	. . .	. . .
Benzosol, ...	ins.	. . .	sol.	. . .
Betol, ...	ins.	. . .	diffic. sol.	. . .
Bismuth Citrate, ...	ins.	. . .	ins.	. . .
" and Ammonium Citrate, . . .	v. s.	. . .	sp.	. . .
" Subcarbonate, ...	ins.	. . .	ins.	. . .
" Subnitrate, ...	ins.	. . .	ins.	. . .
Bromacetanilid, ...	ins.	. . .	diffic. sol.	. . .
Bromamid, ...	ins.	. . .	s. s.	. . .
Bromine, ...	33	13.8	dec.	. .
Bromoform, ...	300	1.5	{ freely sol. }	. . .
Bromol, ...	prac. ins.	. . .	{ freely sol. }	. . .
Caffeine, ...	75	6.08	35	10.6
Caffeine-chloral, ...	s.	. . .	. . .	. . .
Caffeine-tri-iodide, ...	ins.	. . .	s.	. . .
Calcium Bromide, ...	0.7	651.4	1	374
" Carbonate, ...	ins.	. . .	ins.	. . .
" Chloride, ...	1.5	304	8	46.7
" Hypophosphite, ...	6.8	67	ins.	. . .
" Phosphate (precipitated), . .	ins.	. . .	ins.	. . .
Camphor, Monobromated, ...	alm. ins.	. . .	v. s.	. . .
Cerium Oxalate, ...	ins.	. . .	ins.	. . .
Chinolin, ...	ins.	. . .	5	74.8
" Salicylate, ...	80	5.7	sol.	. . .
" Tartrate, ...	80	5.7	150	3.8
Chloral, ...	v. s.	. . .	v. s.	. . .
Chloralamid, ...	10	45.6	2–3	187
Chloral-ammonium, ...	. . .	. . .	. . .	(124.6)
Chloralose, ...	170	2.68	s.	. . .
Chloral Urethan, ...	ins.	. . .	s.	. . .
Cinchonidine Sulphate, ...	100	4.5	71	5.2
Cinchonine, ...	alm. ins.	. . .	110	3.4
" Sulphate, ...	70	6.5	6	62.3
Codeine, ...	80	5.7	v. s.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.—*Continued.*

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.
One part is soluble in—	Parts.		Parts.	
Chalk (Creta), ...	ins.	. . .	ins.	. . .
Copper Acetate, ...	15	30.4	135	2.7
" Sulphate, ...	2.6	175.3	ins.	. . .
Creolin, ...	. . .	. . .	s.	. . .
Creosote, ...	ins.	. . .	v. s.	. . .
" Carbonate, ...	ins.	. . .	s.	. . .
Cresalols, ...	ins.	. . .	s.	. . .
Cresol, Ortho, ...	37	12.3	s.	. . .
" Meta, ...	200	2.28	s.	. . .
" Para, ...	50	9.1	s.	. . .
Cresol Iodide, ...	ins.	. . .	s.	. . .
Cresotic Acids, ...	s. s.	. . .	s.	. . .
Dermatol, ...	ins.	. . .	ins.	. . .
Diaphterin, ...	s.	. . .	s.	. . .
Diaphtol, ...	sp.	. . .	s.	. . .
Di-iodoform, ...	ins.	. . .	sp.	. . .
Di-iodo β-naphthol, ...	ins.	. . .	s. s.	. . .
Dithiosalicylic Acid I, ...	ins.	. . .	ins.	. . .
" " II, ...	ins.	. . .	v. s.	. . .
Diuretin, ...	v. s.	. . .	. . .	. . .
Dulcin, ...	800	.57	25	18.24
Elaterium, ...	ins.	. . .	125	2.9
Ethroxycaffeine, ...	sp.	. . .	s.	. .
Ethyl-bromide, ...	ins.	. . .	s.	. . .
Ethylene Bromide, ...	ins.	. . .	s.	. . .
Euphorin, ...	ins.	. . .	s.	. . .
Europhen, ...	ins.	. . .	s.	. . .
Exalgin.	s. s.	. . .	s.	. . .
Ferric Chloride, ...	v. s.	. . .	v. s.	. . .
" Citrate, ...	s.	. . .	ins.	. . .
" and Ammon. Citrate, ...	v. s.	. . .	ins.	. . .
" " " Sulphate, . . .	3	152	ins.	. . .
" " " Tartrate, . . .	v. s.	. . .	ins.	. . .
" " Potass. Tartrate, . . .	v. s.	. . .	ins.	. . .
" " Quinine Citrate, . . .	s.	. . .	ins.	. . .
" " Strychnine Citrate, . . .	v. s.	. . .	ins.	. . .
" Hypophosphite, ...	sp.	. . .	ins.	. . .
" Lactate, ...	40	11.4	alm. ins.	. . .
" Oxalate, ...	sp.	. . .	ins.	. . .
" Hydrate, ...	ins.	. . .	ins.	. . .
" Phosphate, ...	v. s.	. . .	ins.	. . .
" Pyrophosphate, ...	v. s.	. . .	ins.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.—*Continued.*

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.
One part is soluble in—	Parts.		Parts.	
Ferric Sulphate, ...	1.8	253.3	ins.	. . .
" Valerianate, ...	ins.	. . .	v. s.	. . .
Fluoresceïn, ...	s.	. . .	. . .	. . .
Formanilid, ...	s.	. . .	s.	. . .
Formicaldehyde, ...	v. s.	. . .	v. s.	. . .
Gallacetophenone, ...	500	0.9	s.	. . .
Gallanol, ...	alm. ins.	. . .	s.	. . .
Gallobromol, ...	12	38	s.	. . .
Guaiacol, ...	85	5.3	s.	. . .
" carbonate, ...	ins.	. . .	sp.	. . .
" crystalline, ...	50	9.1	s.	. . .
" salicylate, ...	ins.	. . .	sp.	. . .
Hydracetin, ...	50	9.1	s.	. . .
Hydronaphthol, ...	s. s.	. . .	s.	. . .
Hydroquinone, ...	s. s.	. . .	s.	. . .
Hydroxylamine Hydrochlorate, . . .	1	456	15	23.6
Hyoscyamine Sulphate, ...	v. s.	. . .	v. s.	. . .
Hypnal, ...	5–6	91.2–76	. . .	. . .
Hypnone, ...	ins.	(76)	s.	. . .
Ichthyol, ...	v. s.	. . .	s. s.	. . .
Iodoantipyrin, ...	s. s.	. . .	s. s.	. . .
Iodine, ...	sp.	. . .	11	34
Iodoform, ...	ins.	. . .	80	4.65
Iodol, ...	ins.	. . .	3	124.6
Iodophenin, ...	. . .	. . .	s.	. . .
Kairin, ...	6	76	20	13.7
Lactophenin, ...	s.	. . .	s.	. . .
Lanolin, ...	ins.	. . .	80 at (78° C.)	4.7
Lime (Calx), ...	750	0.6	ins.	. . .
Lithium Benzoate, ...	4	114	12	31.1
" Bromide, ...	v. s.	. . .	v. s.	. . .
" Carbonate, ...	130	3.5	ins.	. . .
" Citrate, ...	5.5	82.9	sp.	. . .
" Salicylate, ...	v. s.	. . .	v. s.	. . .
Loretin, ...	500	0.9	s.	. . .
Losophan, ...	sp.	. . .	s.	. . .
Lycetol, ...	s.	. . .	. . .	. . .
Lysol, ...	v. s.	. . .	v. s.	. . .
Magnesium Oxide, ...	alm. ins.	. . .	ins.	. . .
" Carbonate, ...	alm. ins.	. . .	ins.	. . .
" Sulphate, ...	0.8	570	ins.	. . .

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN MEDICINE, IN WATER AND ALCOHOL.—*Continued*.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F. or 15° C., Grs. pr. f℥j.
One part is soluble in—	Parts.		Parts.	
Magnesium Sulphite, ...	20	22.8	ins.	. . .
Malakin, ...	alm. ins.	. . .	diffic. sol.	. .
Manganesium Dioxide (Black Oxide), .	ins.	. . .	ins.	. . .
" Sulphate, ...	0.7	651.4	ins.	. . .
Mercuric Chloride, ...	16	28.5	3	124
Mercurous Chloride, ...	ins.	. . .	ins.	. . .
Mercuric Cyanide, ...	12.8	35.6	15	24.9
" Iodide (Red), ...	alm. ins.	. . .	130	2.8
Mercurous Iodide (Green), ...	alm. ins.	. . .	ins.	. . .
Mercuric Oxide, ...	ins.	. . .	ins.	. . .
" Subsulphate, ...	ins.	. . .	ins.	. . .
" Sulphide (Red), ...	ins.	. . .	ins.	. . .
Mercury Sozoiodol, ...	500	0.9	. . .	. . .
Metaldehyde, ...	ins.	. . .	s.	. . .
Methacetin, ...	530	0.8	s.	. . .
Methylal, ...	3	152	s.	. . .
Methyl Chloride, ...	4 vol.	. . .	35 vol.	. . .
Methylene (Blue), ...	s. s.	. . .	s.	. . .
" Chloride, ...	s. s.	. . .	s.	. . .
Microcidin, ...	3	152	. . .	. . .
Monobromphenol, ...	sp.	. . .	s.	. . .
Monochlorphenol, ...	sp.	. . .	s.	. . .
Morphine, ...	v. sp.	. . .	100	3.7
" Acetate, ...	12	38	68	5.5
" Hydrochlorate, ...	24	19	63	5.9
" Sulphate, ...	24	19	702	0.5
Naphthalene, ...	1000	0.4	s.	. . .
Naphtol, ...	1000	0.4	s.	. . .
Neurodin, ...	s. s.	. . .	. . .	. . .
Oleocreosote, ...	ins.	. . .	s. s.	. . .
Orexin Hydrochlorate, ...	v. s.	. . .	v. s.	. . .
a-Oxynaphtoic Acid, ...	ins.	. . .	10	37.4
Paraformic Aldehyde, ...	s.	. . .	s.	. . .
Paraldehyde, ...	10	45.6	s.	. . .
Pental, ...	ins.	. . .	v. s.	. . .
Phenacetin, ...	ins.	. . .	s. s.	. . .
Phenocoll Acetate, ...	3.5	130.2	. . .	. . .
" Carbonate, ...	ins.	. . .	. . .	. . .
" Hydrochlorate, ...	16	28.5	. . .	. . .
" Salicylate, ...	s.	.	. . .	. . .
Phosphorus, ...	ins.	. . .	v. sp.	. . .
Physostigmine Salicylate, ...	130	3.5	12	31.1

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN
MEDICINE, IN WATER AND ALCOHOL.—*Continued*.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.
One part is soluble in—	Parts.		Parts.	
Picrotoxine, ...	150	30.4	10	37.4
Pilocarpine Hydrochlorate, ...	v. s.	. . .	v. s.	. . .
Piperazine, ...	v. s.	. . .	. . .	. . .
Piperine, ...	alm. ins.	. . .	30	12.4
Plumbic Acetate, ...	1.8	253.3	8	46.7
" Carbonate, ...	ins.	. . .	ins.	. . .
" Iodide, ...	2000	0.2	v. sp.	. . .
" Nitrate, ...	2	228	alm. ins.	. . .
" Oxide, ...	ins.	. . .	ins.	. . .
Potassium Hydrate, ...	0.5	912	2	187
" Acetate, ...	0.4	1140	2.5	149.6
" Bicarbonate, ...	3.2	142.5	alm. ins.	. . .
" Bichromate, ...	10	45.6	ins.	. . .
" Bitartrate, ...	210	2.1	v. sp.	. . .
" Bromide, ...	1.6	285	200	1.8
" Carbonate, ...	1	456	ins.	. . .
" Chlorate, ...	16.5	27.6	v. sp.	. . .
" Citrate, ...	0.6	760	v. sp.	. . .
" Cyanide, ...	2	228	sp.	. . .
" and Sodium Tartrate, . . .	2.5	182.4	alm. ins.	. . .
" Ferrocyanide, ...	4	114	ins.	. . .
" Hypophosphite, ...	0.6	760	7.3	51
" Iodide, ...	0.8	570	18	20.7
" Nitrate, ...	4	114	alm. ins.	. . .
" Permanganate, ...	20	22.8	dec.	. . .
" Sozoiodol, ...	50	9.12	. . .	. . .
" Sulphate, ...	9	50.6	ins.	. . .
" Sulphite, ...	4	114	sp.	. . .
" Tartrate, ...	0.7	651.4	alm. ins.	. . .
Pyoctanin Blue (Methyl-violet), . . .	50 (?)	. . .	. . .	. . .
Pyridin, ...	. . .	. . .	1	374
Pyrocatechin, ...	s.	. . .	s.	. . .
Quinidine Sulphate, ...	100	4.5	8	46.7
Quinine, ...	1600	0.2	6	62.3
" Bisulphate, ...	10	45.6	32	11.6
" Hydrobromate, ...	16	28.5	3	124.6
" Hydrochlorate, ...	34	13.4	3	124.6
" Sulphate, ...	740	0.6	65	5.7
" Valerianate, ...	100	4.5	5	74.8
Resopyrin, ...	ins.	. . .	5	75
Resorcin, ...	2	228	s.	. . .
Sugar, Cane-, ...	0.5	912	175	2.1

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN
MEDICINE, IN WATER AND ALCOHOL.—*Continued*.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F. or 15° C., Grs. pr.f3j.	At 59° F., or 15° C.	At 59° F. or 15° C., Grs. pr. f3j.
One part is soluble in—	Parts.		Parts.	
Sugar, Milk-,	7	65.1	ins.	. . .
Saccharin,	400	1.14	30	124.6
Salacetol,	ins.	. . .	15	30.4
Salicylamid,	250	1.82	s.	. . .
Salipyrin,	s. s.	. . .	s.	. . .
Salocoll,	200	2.28	s.	. . .
Salol,	ins.	. . .	10	37.4
Salophen,	ins.	. . .	v. s.	. . .
Salicin,	28	16.2	30	12.4
Santonin,	alm. ins.	. . .	40	9.3
Silver Cyanide,	ins.	. . .	ins.	. . .
" Iodide,	ins.	. . .	ins.	. . .
" Nitrate,	0.8	570	26	17.5
" Nitrate (fused),	0.6	760	25	18.24
" Oxide,	v. sp.	. . .	ins.	. . .
Sodium Hydroxide,	1.7	268.2	v. s.	. . .
" Acetate,	3	152	30	12.4
" Arsenate,	4	114	v. sp.	. . .
" Benzoate,	1.8	253.3	45	8.3
" Bicarbonate,	12	38	ins.	. . .
" Bisulphite,	4	114	72	5.2
" Borate (Borax),	16	28.5	ins.	. . .
" Bromide,	1.2	380	13	28.7
" Carbonate,	1.6	285	ins.	. . .
" Chlorate,	1.1	414.5	40	9.3
" Chloride,	2.8	162.8	alm. ins.	. . .
" Hypophosphite,	1	456	30	12.4
" Hyposulphite,	1.5	304	ins.	. . .
" Iodide,	0.6	760	1.8	207
" Nitrate,	1.3	350.7	sp.	. . .
" Paracresotate,	. . .	. . .	. . .	. . .
" Phosphate,	6	76	ins.	. . .
" Pyrophosphate,	12	38	ins.	. . .
" Salicylate,	1.5	304	6	62.3
" Santoninate,	3	152	12	31.1
" Sozoiodol,	14	32.5	. . .	. . .
" Sulphate,	2.8	162.8	ins.	. . .
" Sulphite,	4	114	sp.	. . .
" Sulphocarbolate,	5	91.2	132	2.8
Sozal,	s.	. . .	s. s.	. . .
Sozoiodol,	s.	. . .	s.	. . .
Strychnine,	6700	0.06	110	3.4

SOLUBILITY OF THE MOST IMPORTANT CHEMICALS USED IN
MEDICINE, IN WATER AND ALCOHOL.—*Continued*.

NAME OF CHEMICAL.	WATER.		ALCOHOL.	
	At 59° F., or 15° C.	At 59° F., or 15° C. Grs. pr. f℥j.	At 59° F., or 15° C.	At 59° F. or 15° C. Grs. pr. f℥j.
One part is soluble in—	Parts.		Parts.	
Strychnine Sulphate, ...	10	45.6	60	6.2
Sulphaminol, ...	ins.	. . .	s.	. . .
Sulphonal, ...	450	1.01	65	5.8
Sulphosalicylic Acid, ...	s.	. . .	s.	. . .
Sulphur, ...	ins.	. . .	ins.	. . .
Symphorol L, ...	s.	. . .	alm. ins.	. . .
" N, ...	50	9.1	alm. ins.	. . .
" S, ...	s.	. . .	alm. ins.	. . .
Tetronal, ...	450	1.01	s.	. . .
Thallin Sulphate, ...	7	65.1	100	1.8
" Tartrate, ...	10	45.6	s. s.	. . .
Thermodin, ...	s.	. . .	. . .	. . .
Thioform, ...	ins.	. . .	ins.	. . .
Thiol, ...	s.	. . .	s.	. . .
Thiophen, ...	ins.	. . .	. . .	. . .
Thioresorcin, ...	. . .	. . .	s. s.	. . .
Thiosinamin, ...	s. s.	. . .	s.	. . .
Thiuret, ...	350	1.3	ins.	. . .
Thymacetin, ...	s. s.	. . .	. . .	. . .
Thymol, ...	1200	0.38	1	37.4
Trional, ...	320	1.4	s.	. . .
Urethan, ...	1	456	0.6	623
Uropherin, ...	s.	. . .	. . .	. . .
Veratrine, ...	v. sp.	. . .	3	124.6
Zinc Acetate, ...	3	152	30	12.4
" Bromide, ...	v. s.	. . .	v. s.	. . .
" Carbonate, ...	ins.	. . .	ins.	. . .
" Chloride, ...	v. s.	. . .	v. s.	. . .
" Iodide, ...	v. s.	. . .	v. s.	. . .
" Oxide, ...	ins.	. . .	ins.	. . .
" Phosphide, ...	ins.	. . .	ins.	. . .
" Sozoiodol, ...	20	22.8	s.	. . .
" Sulphate, ...	0.6	760	ins.	. . .
" Valerianate, ...	100	4.5	40	9.3

GLOSSARY

OF UNUSUAL CHEMICAL TERMS.

[The figures in parenthesis refer to the pages of this book, where a fuller explanation may be found.]

A.

ACTINISM. The chemical effects of light.

Areometer. Hydrometer. (21.)

Ærugo. Verdigris. Impure subacetate of copper.

Æthiops. Black sulphide of mercury. Hg_2S.

Alabaster. A light-colored, compact gypsum. $CaSO_4$. (264.)

Alchemy. The Arabic name for chemistry, which formerly arose out of the search for the philosopher's stone and the elixir of life.

Alembic. A form of still or retort, used in sublimation.

Alkarsin. Oxide of cakodyl, or cacodylic acid. $As(CH_3)_2O_2H$.

Alloy. A mixture or compound formed by fusing two or more metals together.

Amidon. Starch. (373.)

Amorphous. Without a definite crystalline form.

Anhydride. An oxide which can combine with the elements of water to produce an acid. Hence, an acid deprived of one or more molecules of water.

Anode. The + pole of a voltaic circuit.

Apple Oil. Valerianate of amyl.

Aqua Fontana. Aqua, U. S. P.

Aqua Fortis. Crude nitric acid. (180.)

Aqua Phagedænica. Yellow wash. Mercuric hydrate.

Aqua Regia. Nitromuriatic acid. (181.)

Aqua Vitæ. Brandy.

Argols. Crude cream of tartar. (247.)

Arrack. A spirituous drink made from the juice of the cocoanut tree.

Auripigmentum. Orpiment. Arsenous sulphide.

Austral. The south pole of a magnet.

Azote. (Fr.) Nitrogen.
Azotic Acid. Nitric acid. (181.)

B.

BALDWIN'S Phosphorus. Fused calcium nitrate; possibly luminous calcium sulphide.

Balsam of Sulphur. A solution of S. in olive oil.

Barilla. The ashes of sea-plants, and **Salsola Soda.**

Basyl. A term applied to an electropositive radical.

Battery. An apparatus for the production of electricity by chemical action. (66.)

Baumé. The name of the inventor of a hydrometer bearing this name.

Bell Metal. An alloy of 6 parts copper and 2 parts tin.

Bestuchuf's Tincture. An ethereal solution of Fe_2Cl_6.

Bibron's Antidote. A solution of $HgCl_2$, Kl, bromine, alcohol, and water.

Bittern. The mother-liquor remaining after extracting NaCl from sea-water by evaporation and crystallization.

Black Ash. Impure Na_2CO_3, mixed with carbon.

Black Drop. Acetum opii. Vinegar of opium.

Black Flux. Made by igniting cream of tartar with one-half its weight of nitre, KNO_3. It contains carbon and K_2CO_3.

Black Lead. Plumbago; a native variety of carbon, used for making lead-pencils, crucibles, and stove-polish. (207.)

Black Salts. The ley of wood-ashes evaporated nearly to dryness.

Black Wash. Contains suboxide of mercury, Hg_2O. (279.)

Bleaching Powder. Chloride of lime. A mixture of chloride and hypochlorite of calcium. (261.)

Blende. Native sulphide of zinc. ZnS. (273.)

Blue Mass. Pilulæ hydrargyri.

Blue Ointment. Unguentum hydrargyri.

Blue Vitriol, or Bluestone. Sulphate of copper. (253.)

Bole. An argillaceous earth.

Bone-ash. Impure Ca_3PO_4, from burning bones. **Bone-black.** (Charred bones.) (209.)

Borax. Biborate of sodium. Tetraborate of sodium, $Na_2B_4O_7$. (238.)

Boreal. The north pole of a magnetic needle.

Brass. An alloy of copper and zinc.

Brimstone. Roll sulphur. (158.)

British Barilla. Black ash.

British Gum. Dextrin. (376.)

Bronze. An alloy of copper and tin.

Brunswick Green. Oxychloride of copper.

Bunsen Burner. A gas-burner used for the production of heat. It mixes the gas and air before burning them.

Burnett's Disinfecting Fluid. Solution of $ZnCl_2$. (171.)

Butter of Zinc, Antimony and Bismuth. Their chlorides.

C.

CALAMINE. Impure, native carbonate of zinc. (273.)

Calcareous Spar. Calcite. $CaCO_3$. (265.)

Calcedony. A native form of SiO_2.

Calcined Mercury. Mercuric oxide. HgO.

Calcining. Igniting a substance in the air, so as to burn off any oxidizable material or expel volatile products.

Calomel. Mercurous chloride. Mild chloride of mercury, Hg_2Cl_2. (278.)

Caloric. Old term for heat.

Calorie. The unit of heat used in determining the heat of combination of chemical compounds. (37.)

Camphene. Oil of turpentine. Camphene burning fluid is a solution of turpentine in alcohol.

Canton's Phosphorus. Luminous CaS, or luminous paint.

Caput Mortuum. The residue left after ignition of $FeSO_4$ or iron pyrites. Impure Fe_2O_3. (298.)

Caramel. Burnt sugar. (367.)

Carbolic Acid. Phenic acid. Phenyl-alcohol. (432.)

Carburet. Carbide.

Catalysis. The action of a body in promoting combination or decomposition by its presence, the body itself remaining unchanged.

Cathode. The negative pole of a galvanic circuit.

Chalk. An amorphous carbonate of lime. (265.)

Chameleon Mineral. Permanganate of potassium.

Choke-damp. Carbonic anhydride. CO_2. (213.)

Chrome Green. A mixture of chrome yellow and Prussian blue; or sesquioxide of chromium. Cr_2O_3. (289.)

Chrome Vermilion. Dichromate of lead. $PbCr_2O_7$.

Chrome Yellow. Chromate of lead. $PbCrO_4$. (229.)

Cinnabar. Native red sulphide of mercury. HgS. (282.)

Citrine Ointment. Nitrate of mercury ointment.

Clay. Impure silicate of alumina.

Clay Ironstone. A variety of hematite iron ore. Fe_2O_3.

Colcothar. Ferric oxide. F_2O_3. Rouge; crocus.

Collodion. Solution of guncotton in alcohol and ether. (375.)

Colloids. Jelly-like or non-crystallizable bodies. (81.)

Colophony. Common resin, or rosin. (322.)

Common Salt. Sodium chloride. NaCl. (232.)

Condy's Solution. Contains permanganate of potassium. $K_2Mn_2O_8$. (293.)

Copperas. Green vitriol. Crystallized ferrous sulphate. $FeSO_4.7Aq.$ (296.)

Corrosive Sublimate. Mercuric chloride. Bichloride of mercury. $HgCl_2$. (279.)

Cream of Tartar. Acid potassium tartrate. $HKC_4H_4O_6$. (247.)

Crocus of Antimony, or Crocus Metallorum. Oxysulphide of antimony. (201.)

Crocus Martis. Colcothar. Fe_2O_3.

Crystalloids. Crystallizable bodies, as distinguished from colloids. (81.)

Crystals of Venus. Copper acetate. $Cu(C_2H_3O_2)_2.H_2O$.

Cubic Nitre. Sodium nitrate. $NaNO_3$.

Cupellation. The process of purifying silver or gold in a **cupel** or cup made of bone-ash. When the alloy is strongly heated in the air, the other metals oxidize, and the cupel absorbs the oxide, leaving the pure silver or gold.

D.

DECANTATION. The process of pouring off the clear liquid above a sediment.

Decoction. An extract of an organic substance, made with boiling water.

Decrepitation. The crackling of certain salts when suddenly heated.

Deflagration. A rapid and scintillating combustion. It takes place in certain mixtures containing the nitrates or chlorates.

Deliquescent. An adjective applied to those substances which attract moisture from the air and liquefy. (82.)

Destructive Distillation. Dry distillation, conducted with the object of destroying the substance and producing new ones. (35.)

Detonation. Rapid chemical action, accompanied by flame and noise. An explosion.

De Valangin's Arsenical Solution. A solution of the chloride. $AsCl_3$. **Liq. Arsen. Hydrochlor.**

Dew-point. The temperature at which the moisture of the air begins to deposit.

Dialysis. The process of the diffusion of liquids and solutions through membranes. (80.)

Dimorphous. Crystallizing in two distinct systems. (81.)

Displacement. Expelling a fluid from a vessel by another of different density.

Dolomite. Magnesium limestone. (270.)

Donovan's Solution. Contains the iodides of arsenic and mercury. (191.)

Dover's Powder. Compound ipecac. powder; contains opium (1 gr. in 10).

Drummond Light. Calcium light.

Dry Distillation. The process of subjecting solid or organic bodies to heat, in a closed retort.

Ductile. Capable of being drawn into wire or rolled out into sheets.

Dutch Gold. A species of brass, usually sold in very thin leaves or sheets.

Dutch Liquid. Ethene dichloride. $C_2H_4Cl_2$.

Dutch White. Impure white lead.

E.

EAU DE JAVELLE. A solution of chlorinated potass. or potass. hydrochlorite. KOCl.

Educts. The proximate principles of which bodies were formerly supposed to be formed.

Effervescence. The rapid escape of gas from a liquid.

Efflorescence. The escape of the water of crystallization and the consequent crumbling down of the crystal. (82.)

Electrode. The pole or wire forming a part of a volatile circuit. (71.)

Electrolysis. Decomposition by means of a strong electric current. (76.)

Element. A substance which has never been decomposed.

Elixir of Vitriol. Aromatic sulphuric acid.

Elutriation. The process of separating the finer and lighter particles of a powder from the coarser, by suspending them in water and pouring off the lighter floating particles with the water.

Emerald Green. Schweinfurth green, or aceto-arsenite of copper. See Paris Green.

Emery. An impure corundum. Al_2O_3. (285.)

Eosin. Tetrabromfluoresceine. A beautiful, red, artificial coloring matter.

Epsom Salt. $MgSO_4.7Aq.$ (271.)

Eremacausis. The slow decay of organic substances in the air.

Essence of Mirbane. Nitrobenzol. (535.)

Essential Oils. Volatile oils.

Eudiometer. A graduated glass tube, closed at one end, used for measuring gases.

F.

FERMENTATION. (547.)

Filter. A porous substance used to separate a solid and a liquid by allowing the latter to pass through, while the former is retained.

Fire-damp. Light carburetted hydrogen (marsh-gas) mixed with air. (316.)

Fixed Air. Choke-damp. CO_2. (213.)

Flint. An impure variety of silica. SiO_2.

Flowers of Antimony. Oxide of antimony.

Flowers of Benzoin. Benzoic acid. (447.)

Flowers of Sulphur. Sulphur sublimatum. U. S. P. (158.)

Flowers of Zinc. Oxide of zinc. ZnO. (274.)

Fluorescence. The property possessed by certain bodies, as quinine salts, of rendering visible the ultra-violet or chemical rays of the solar spectrum.

Fluor Spar. Native calcium fluoride. CaF_2. (121.)

Flux. A material added to ores in smelting, to form an easily fusible slag.

Foliated Earth of Tartar. $KC_2H_3O_2$. Potassium acetate.

Fool's Gold. Iron pyrites.

Fowler's Solution. Solution of the arsenite of potassium. (190.)

French Chalk. Silicate of magnesia. Soapstone; talc.

Fructose. Fruit-sugar. Levulose.

Fuchsine. Aniline red. Magenta. $C_{20}H_{19}N_3$.

Fuming Liquor of Libarius. Solution of stannic chloride.

Fusel Oil. Amylic alcohol. (354.)

Fusible Calculus. One composed of a mixture of phosphate of lime and ammonio-magnesium phosphate.

Fusible Metal. Bismuth 2 parts, lead 1 part, and tin 1 part. Melts at about 200° F.

G.

GALENA. Native lead sulphide. (225.)

Galvano-cautery. A surgical knife heated by galvanic current.

German Silver. An alloy of copper, nickel, and zinc.

Glass. An artificial silicate of calcium, sodium, iron, lead, etc.

Glass of Antimony. Fused trisulphide of antimony. Sb_2S_3.

Glass of Borax. Fused borax.

Glauber's Salt. Sodium sulphate (234.)

Glucose. Grape-sugar. Now made on large scale from cornstarch. (363.)

Glucoside. (See p. 499.)

Glyceroles and Glycerita. Simple glycerin solutions.

Goniometer. An instrument for measuring the angles of crystals.
Goulard's Extract, and Cerate. Contain subacetate of lead.
Graphine. Carbon deposited in gas-retorts.
Graphite. Plumbago. Black lead. (207.)
Green Vitriol. Copperas. $FeSO_4.7Aq.$ (296.)
Guano. A deposit of excrement of sea-fowl.
Gypsum. Calcium sulphate. Plaster-of-Paris. (264.)

H.

HALOGEN Elements. Haloid Salt. The elements of the chlorine group and their binary compounds. (191.)
Harle's Solution. Solution of arsenite of sodium.
Hartshorn. Ammonia. (173.)
Haschisch. Indian hemp.
Hepar Sulphuris. Liver of sulphur. Potassium sulphide.
Hive Syrup. Compound syrup of squills.
Hoffman's Anodyne. Spirit. Æther. Co. Ether, 1 pint; alcohol, 1 pint; ethereal oil, f3vj.
Homberg's Pyrophyrus. Made by igniting potassium, alum, and charcoal.
Homologous Series. (311.)
Homologues. (312.)
Huxham's Tincture. Compound tincture of cinchona.
Hydracid. A binary acid. Contains no oxygen.
Hydrate. A compound containing hydroxyl, HO, combined to a positive radical.
Hydrochloride. A compound of HCl, formed by the union of the whole molecule by synthesis; as compounds with the alkaloids.
Hydroxide. Same as a hydrate.
Hygrometer. An instrument for the determination of the relative amount of moisture in the air.

I.

ICE Vinegar. Glacial acetic acid. (417.)
Incandescence. The glow of a highly heated body.
Incineration. The reduction of a substance to ashes by burning.
Incompatible. Incapable of being mixed without chemical change.
Infusion. An extract of an organic substance, made by pouring hot water upon it and allowing it to stand for some hours. (154.)
Inosite. Muscle-sugar. (365.)
Ion. A body going to the positive (anode) or negative (cathode) pole of a galvanic battery during electrolysis.

Iron Pyrites. Native sulphide of iron. Fool's gold.

Isinglass. A variety of gelatin, or fish-glue. Sometimes erroneously applied to mica.

Ivory Black. Animal charcoal, made by distilling ivory scraps; is now generally applied to bone-black.

J.

JAMES' Powder. Antimonial powder.

Japan Black. A varnish composed of asphaltum, turpentine, linseed oil, and umber.

Jesuits' Powder. Powdered cinchona-bark.

K.

KAOLIN. A pure white clay.

Kelp. Ashes of seaweeds; used as a source of iodine and carbonate of sodium.

Kermes' Mineral. Sb_2O_3. (201.)

King's Yellow. Orpiment. As_2S_3.

Kyan's Disinfectant. Solution of $HgCl_2$.

L.

LABARRAQUE'S Disinfecting Liquid. Solution of hypo-chlorite of sodium or chlorinated soda. (238.) (173.)

Lac Sulphuris. Precipitated sulphur. (159.)

Lacquer. A varnish used for brass, etc.

Lactin—Lactose. Sugar of milk. (367.)

Lady Webster Pill. Pill of aloes.

Lake. An organic coloring matter precipitated with aluminum hydrate. Used as pigments.

Lampblack. The soot of burning turpentine. (207.)

Lana Philosophica. Oxide of zinc. (274.)

Lapis Infernalis. Lunar caustic. $AgNO_3$.

Laughing Gas. Nitrous oxide. N_2O. Dentists' gas. (176.)

Lead-water. Diluted Goulard's Extract, containing subacetate of lead. (229.)

Ledoyen's Disinfecting Liquid. Solution of nitrate of lead. (171.)

Levigation. The reduction of a substance to an impalpable powder by rubbing on a slab with a flat pestle, called a muller, with sufficient water to form a paste.

Lime. CaO. (262.)
Limestone. A native carbonate of lime. (261.)
Litharge. PbO. Semivitrified oxide of lead. (226.)
Lithic Acid. Uric acid. (466.)
Liver of Sulphur. Potass. sulphuret. K_2S. (246.)
Lixiviation. The separation of the soluble portions of a substance by causing water to filter through it. (154.)
Loadstone. The native magnetic oxide of iron, or magnetite. A magnet. (298.)
Lugol's Solution. Compound solution of iodine. Iodine held in solution by Ki. (130.)
Lunar Caustic. Nitrate of silver. $AgNO_3$. (257.)
Lute. An adhesive mixture for closing the joints of apparatus, to prevent the escape of vapors, etc.

M.

MACERATION. The long-continued soaking of a substance in water at common temperatures. (154.)
Macquer's Salt. Potassium arsenate.
Magendie's Solution. Morph. sulphate, gr. xvj ; water, f$_3$j.
Magistery of Bismuth. Subnitrate.
Magma. A pasty mass.
Magnesia Alba. Magnesium carbonate. (272.)
Malleable. Capable of being worked under the hammer.
Marble. Nearly pure native carbonate of lime. (265.)
Marine Acid. Muriatic acid. Hydrochloric acid. HCl. (125.)
Martial Æthiops. Fe_3O_4. Magnetic oxide of iron.
Massicot. Amorphous oxide of lead. PbO. Powdered litharge. (226.)
Matrass. A glass vessel with a long neck, or a tube sealed at one end. Used for heating dry substances.
Menstruum. A solvent, or medium of chemical reaction.
Mercaptan. An alcohol in which O is replaced by sulphur.
Metalloid. Non-metal. (112.)
Metameric Bodies. The same as isomeric. (313.)
Microcosmic Salt. $NaNH_4HPO_4$.
Milk of Lime. Whitewash. (263.)
Milk of Sulphur. Precipitated sulphur.
Mineral Water. Water charged with carbonic acid ; also natural water holding medicinal substances in solution. (153.)
Mineral Yellow. Oxychloride of lead.
Minium. Red oxide of lead. $2PbO.PbO_2$. (227.)
Molecule. (84.)

Monsel's Salt. Subsulphate of iron. (298.)
Mordant. A substance used to fix colors on fabrics.
Mosaic Gold. Brass.
Mountain Blue. Azurite. Native basic carbonate of copper.
Mountain Green. Malachite. A native basic carbonate of copper.
  (254.)
Mulberry Calculus. Calcium oxalate. CaC_2O_4.
Muriate. A chloride.
Muriatic Acid. Hydrochloric acid. (125.)

N.

NAPHTHA. A light hydrocarbon obtained from petroleum, and
  boiling at about 80° to 105° C. (334.)
Natron. Native carbonate of sodium.
Neutral. Without action on test-paper. Neither acid nor alkaline.
Neutral Mixture. Solution of citrate of potassium.
Nitre. Saltpeter. KNO_3. (244.)
Normal Salt. Neither acid nor basic.

O.

OBSIDIAN. Volcanic glass.
Ochre. A native mixture of clay and ferric oxide, used as a paint.
Oil of Vitriol. H_2SO_4. Sulphuric acid. (163.)
Oil of Wine. Ethyl-sulphate. $(C_2H_5)_2SO_4$.
Oreide. A species of brass resembling gold, and used for jewelry.
Orpiment. Arsenous sulphide. As_2S_3. (190.)
Ortho-acid. An acid in which each bond of the kernel is united to
  hydroxyl. (OH.)
Osmosis. The diffusion of liquids through porous septa. See
  Dialysis. (80.)
Ox-acid. A ternary acid containing oxygen.

P.

PACKFONG. A variety of German silver.
Paris Green. Impure Schweinfurth green. Aceto-arsenite of cop-
  per. (254.)
Particle. A minute portion of matter.
Pearl Ash. Impure carbonate of potassium. (245.)
Pearl Powder. Subnitrate, or oxychloride of bismuth. ($BiONO_3$,
  or BiOCl.)

Pearl White. $BiONO_3$, or BiOCl.

Pearson's Salt. Arsenate of sodium. Na_3AsO_4.

Pewter. An alloy of variable composition. Usually composed of tin, lead, copper, and antimony, or zinc.

Pinchbeck Gold. A species of brass.

Plaster-of-Paris. Calcium sulphate. Calcined gypsum. (264.)

Platinum Black, and Sponge. Finely divided platinum. (302.)

Plumbago. Native carbon. Graphite. (207.)

Potash. Impure carbonate of potassium.

Potassa. Oxide or hydrate of potassium.

Powder of Algaroth. Oxychloride of antimony. (201.)

Precipitate. An insoluble substance formed on bringing two or more substances together in solution.

Precipitatum Per Se. Mercuric oxide. HgO. Made by heating mercury to near its boiling point until it oxidizes.

Preston Salts. Carbonate of ammonia, flavored with some essential oil.

Prussian Blue. Ferric ferrocyanide. (221.)

Prussic Acid. Hydrocyanic acid. (535.)

Pseudomorph. A mineral crystallized in the form that belongs to another mineral.

Puce-oxide of Lead. Lead peroxide, or brown oxide.

Purgative Mineral Water. Liq. magnes. citrat.

Purple of Cassius. A pigment produced by treating chloride of gold with a solution of stannous chloride. (259.)

Putty. Composed of whiting and linseed oil.

Putty Powder. Stannic oxide.

Pyrites. Native sulphide of iron.

Pyroxilic Spirit. Wood-alcohol. Methyl-alcohol. (349.)

Pyroxylin. Guncotton. Trinitrocellulose. (375.)

Q.

QUANTIVALENCE. Quantity of combining power; applied to atoms. (See Equivalence.)

Quartz. SiO_2. (222.)

Quevenne's Iron. Ferrum redactum. (295.)

Quicklime. Caustic lime. CaO. (262.)

Quicksilver. Mercury. (277.)

R.

RADICAL. An atom, or group of atoms, forming the basis of a series of compounds. (95.)

Radical Vinegar. Glacial acetic acid.

Realgar. Red sulphide of arsenic. (191.)
Red Precipitate. Red oxide of mercury. HgO. (281.)
Red Prussiate of Potash. Ferricyanide of potassium. (221.)
Red Tartar. Argol. (428.)
Regulus of Antimony. Metallic antimony.
Roche, and Roman Alums. Varieties of potassium alum.
Rochelle Salt. Tartrate of potassium and sodium. (247.)
Rock Crystal. Quartz. SiO_2. (222.)
Roman Vitriol. Sulphate of copper. $CuSO_4$.
Rouge. Ferric oxide in fine powder. Fe_2O_3.
Ruby. Native Al_2O_3, of a beautiful red color. (285.)
Rust. Ferric oxide; generally containing some ferric hydrate.

S.

SACCHARUM Saturni. Acetate of lead. (228.)
Safety Lamp. A lamp inclosed in wire gauze to prevent explosions of explosive gases in mines, cellars, etc.
Sal Æratus. Potassium bicarbonate.
Sal Alembroth. Double chloride of mercury and ammonium. (278.)
Sal Ammoniac. Ammonium chloride. (248.)
Sal Diureticus. Potassium acetate.
Sal Enixum. Potassium bisulphate.
Sal Mirabile. Sodium sulphate.
Sal Perlatum. Sodium phosphate.
Sal Prunelle. Fused nitre. KNO_3.
Sal Volatile. Ammonium carbonate.
Salt of Lemon and Salt of Sorrell. Potassium binoxalate. (246.)
Salt of Phosphorus. Microcosmic salt.
Salt of Saturn. Acetate of lead. (228.)
Salt of Tartar. Pure potassium carbonate. (245.)
Saltpeter. Potassium nitrate. (244.)
Sapphire. A native form of Al_2O_3, of a blue color. (285.)
Scheele's Green. Arsenite of copper. (192.)
Schlippe's Salt. Sodium sulphantimoniate. Na_3SbS_4.
Schweinfurth Green. Copper aceto arsenite. (254.)
Seidlitz Powder. A mixture of sodium bicarbonate and Rochelle salt in one paper and tartaric acid in another.
Seignette's Salt. Rochelle salt, $KNaC_4H_4O_6$. (247.)
Sienna. A native red pigment. An impure oxide of iron.
Sizing. A gelatinous mixture put into paper or cloth, to fill up the pores.
Slag. The fused impurities from smelting of ores. (295.)
Smalt. Glass colored blue by oxide of cobalt and powdered.
Smelting. The process of recovering the metals from their ores.

Soapstone. Talc. (270.)
Soda-ash. Crude sodium carbonate. (236.)
Soda-saltpeter. Sodium nitrate. $NaNO_3$. (238.)
Soda-water. Water artificially charged with CO_2 under pressure.
Solder. An alloy of tin and lead.
Soluble Glass. See Water Glass. (223.)
Soluble Tartar. Neutral potassium tartrate. (246.)
Speculum Metal. An alloy of copper and tin.
Speiss. Impure, fused nickel arsenide.
Spelter. Commercial zinc.
Spermaceti. A fat obtained from the sperm whale.
Spirit of Hartshorn. Spirit of ammonia. Solution of ammonia in alcohol.
Spirit of Mindererus. Solution of ammonium acetate. (250.)
Spirits of Nitre. Nitric acid. (383.)
Spirit of Salt. Muriatic acid. (125.)
Spirit of Wine. Alcohol.
Steinbuhl Yellow. Barium chromate. $BaCrO_4$.
Substitution. The displacement of an atom in a molecule by another atom of a different kind.
Sugar of Lead. Lead acetate. (228.)
Sulphuret. Sulphide.
Sulphuric Æther. Ethylic ether. $C_4H_{10}O$. (379.)
Sulphur Vinum. Impure sulphur. Horse-brimstone.

T.

TALMI Gold. An alloy of copper and aluminum.
Tartar Emetic. Antimonyl potassium tartrate. (247.)
Tasteless Purging Salt. Sodium phosphate.
Thenard's Blue. A compound of the oxides of aluminum and cobalt.
Tincal. Native borax. $Na_2B_4O_7$. (238.)
Tincture. A solution in alcohol. When in ether it is called an ethereal tincture.
Tombac. A kind of brass.
Tournesol. Litmus.
Trituration. Rubbing in a mortar.
Trona. Native sodium carbonate.
Tully's Powder. Compound morphine powder.
Turnbull's Blue. Ferrous ferricyanide. (221.)
Turner's Cerate. Calamine cerate.
Turner's Yellow. Lead oxychloride.
Turpeth Mineral. Yellow sulphate of mercury. (282.)

Tutty. Impure zinc oxide.

Type-metal. An alloy of lead and antimony. (200.)

U.

ULTRAMARINE. Lapis-lazuli. A compound of aluminum sodium silicate with sodium sulphide. A beautiful blue pigment. It is now prepared artificially, as well as a green, red, and violet variety.

Umber. A native silicate of aluminum, with oxides of iron and manganese. Used as a brown paint.

V.

VALENCE of Atoms. Quantity of combining power. (92.)

Vallet's Mass. $FeCO_3$ made into a pill-mass.

Varec. Kelp. Ash of seaweeds.

Verd Antique. Precious serpentine.

Verdigris. Impure copper subacetate. (254.)

Verditer. Basic copper carbonate.

Vermilion. Artificial mercuric sulphide. HgS. (282.)

Vitriolic Acid. Sulphuric acid. (163.)

W.

WATER Glass. Soluble glass. Sodium silicate. (223.)

White Arsenic. Arsenous oxide.

White Lead. A basic lead carbonate. (228.)

White Precipitate. Ammoniated mercury. Mercur-amidogen chloride. NH_2HgCl. (280.)

White Vitriol. Zinc sulphate. (275.)

Whiting. Prepared chalk. $CaCO_3$. White clay, often sold for whiting.

Wood-naphtha and Wood-spirit. Methyl-alcohol. (349.)

Wood-vinegar. Pyroligneous acid. Impure acetic acid. (417.)

Y.

YELLOW Prussiate of Potash. Potassium ferrocyanide. (221.)

Yellow Wash. Made by adding corrosive sublimate to lime-water. It forms mercuric oxide. (280.)

Z.

ZAFFRE. Impure cobalt oxide.

Zinc White. Zinc oxide. Used as a paint. (275.)

Zymosis. The peculiar action caused by a ferment.

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